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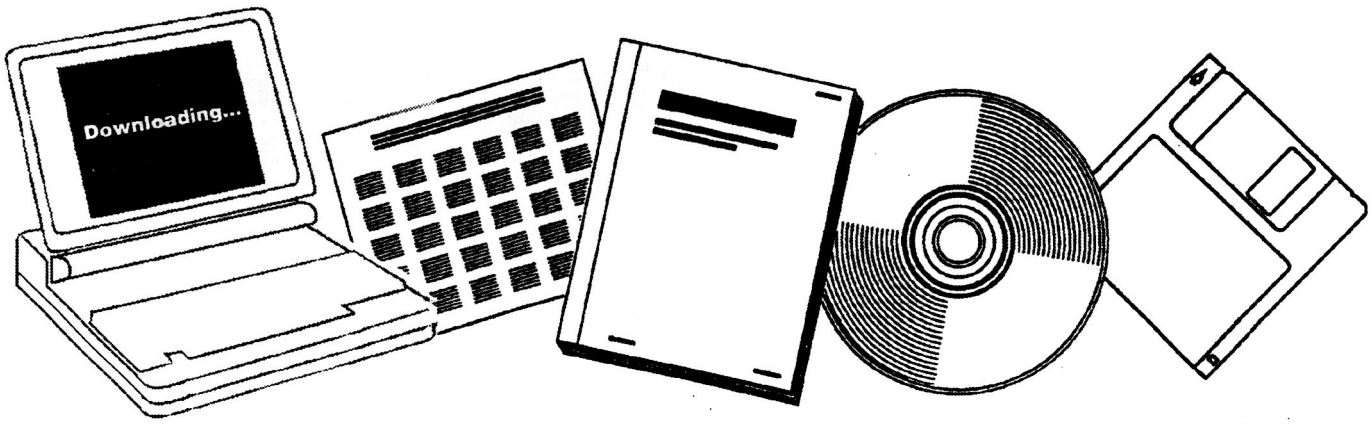
DESIGN AND FABRICATION OF THE BRAYTON CYCLE HIGH PERFORMANCE COMPRESSOR RESEARCH PACKAGE FINAL REPORT

AIRESEARCH MFG. CO., PHOENIX, ARIZ

29 NOV 1967



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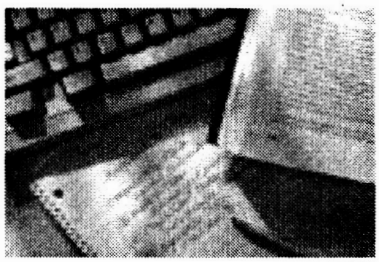

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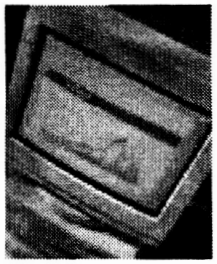

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Technology Administration

NASA CR-72533
APS-5269-R

FINAL REPORT
DESIGN AND FABRICATION
OF THE BRAYTON CYCLE HIGH PERFORMANCE
COMPRESSOR RESEARCH PACKAGE

Prepared for

National Aeronautics and Space Administration

by

AiResearch Manufacturing Company of Arizona

November 29, 1967

Contract NAS3-9427

Technical Management

NASA Lewis Research Center
Cleveland, Ohio

Space Power Systems Division

James H. Dunn

AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

ABSTRACT

AiResearch Manufacturing Company of Arizona designed, fabricated, performed acceptance testing and delivered to the NASA a Brayton-Cycle Compressor Research Package under NASA Contract NAS3-9427.

The research package is aerodynamically identical to the compressor used in the NASA Brayton Rotating Units (BRU) to be delivered under the same contract. This compressor research package will be utilized at the NASA Lewis Research Center for complete component performance evaluation.

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FINAL REPORT
DESIGN AND FABRICATION
OF THE BRAYTON CYCLE HIGH PERFORMANCE
COMPRESSOR RESEARCH PACKAGE

1.0 INTRODUCTION

This report submitted by the AiResearch Manufacturing Company of Arizona, a division of the Garrett Corporation, describes the design, fabrication, inspection and acceptance testing of the NASA Brayton-Cycle Compressor Research Package.

The research package consists of a 4.25-inch diameter compressor wheel and shaft mounted on ball bearings and the associated mounting hardware. The aerodynamic passages of the impeller and diffuser are identical to the compressor of the Brayton Rotating Units (BRU) to be delivered under the same contract.

The Compressor Research Package underwent a mechanical integrity spin-up test as reported in the acceptance test section of this report. Subsequently, the research package was shipped to the NASA-Lewis Research Center in accordance with the contract requirements.

2.0 DETERMINATION OF DESIGN CONDITIONS

During the preliminary design phase of the BRU Program, system studies were performed to determine trends toward establishing the optimum BRU configuration and its corresponding design points at three representative power levels--2.25 kw_e, 6.0 kw_e, and 10.5 kw_e net electrical output. Extensive parametric analysis evolved a system design which yielded high cycle efficiency and conditions favorable to the BRU throughout the 2.25 kw_e to 10.5 kw_e power range.

The compressor design conditions resulting from that analysis at the reference design power level of 6.0 kw_e are as follows:

Working fluid	XeHe mixture, equivalent molecular weight = 83.8
Compressor inlet pressure (total)	13.5 psia
Compressor inlet temperature (total)	540°R
Compressor pressure ratio	1.9
Compressor mass flow rate	0.756 lb/sec.
Compressor rotating speed	36,000 rpm
Compressor specific speed	0.11

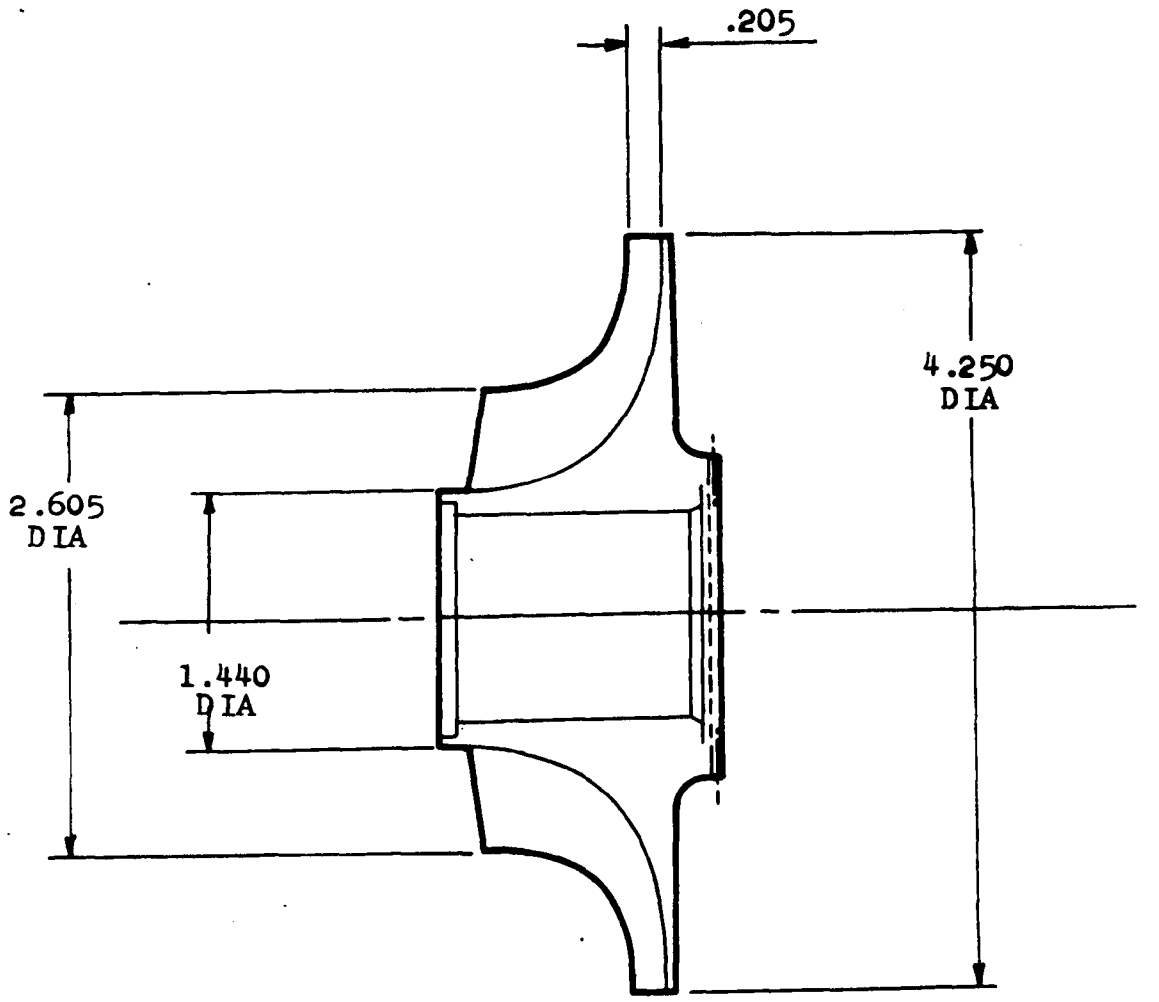
3.0 COMPRESSOR DESIGN

3.1 Aerodynamic Design Approach

After reviewing the compressor design conditions obtained from the system analysis, it was determined that an exact scale of an existing compressor stage would yield excellent efficiency. To assist in reaching this conclusion, the measured performance of the existing compressor was utilized, in a computer program to predict the performance in the XeHe mixture and appropriate corrections were made to account for expected efficiency changes. Similar past performance predictions based on air data for compressors to be operated in gases other than air have proven to be reliable.

The only new component required--the scroll--was designed to provide a minimum total pressure loss from the diffuser exit to the scroll exit using standard scroll design practice. In addition, only minor mechanical diffuser modification would be required. Further study indicated that based on the existing technology, it was not likely that a new compressor designed specifically for the BRU would exceed the expected efficiency of a scaled stage. Estimates of efficiency deterioration due to lower Reynold's number, smaller and less accurate parts, and higher relative axial clearance led to a predicted design efficiency of greater than 80 percent.

The final calculated scale factor was 0.514. The meridional dimensions of the scaled wheel are given in Figure 1.



BRU COMPRESSOR WHEEL

FIGURE 1

The compressor wheel from which the BRU has been scaled is typical of the latest generation of small centrifugal compressors which employ backward curved blading (the blade is not radial at the exit). Using advanced analysis techniques and sophisticated development procedures, this type of design has exhibited consistently high efficiencies over a wide range of pressure ratios.

3.2 Aerodynamic Design Data

The following is a tabulation of the aerodynamic design data, for the compressor.

(a) Velocity vector diagrams.
(See Figure 2 for impeller velocity diagrams and Figure 3 for diffuser and scroll velocity diagrams).

(b) Efficiencies
(See Table 1)

(c) Pressure ratios
Total-to-total pressure ratio = 1.900
Total-to-static pressure ratio = 1.981

(d) Actual specific work = 16.58 hp per lb per sec.

(e) Weight flow = 0.756 lb per sec.

(f) Stator and rotor physical dimensions
(See Figure 4)

(g) Total and static pressures at inlet and exit of stator and rotor (See Table 1)

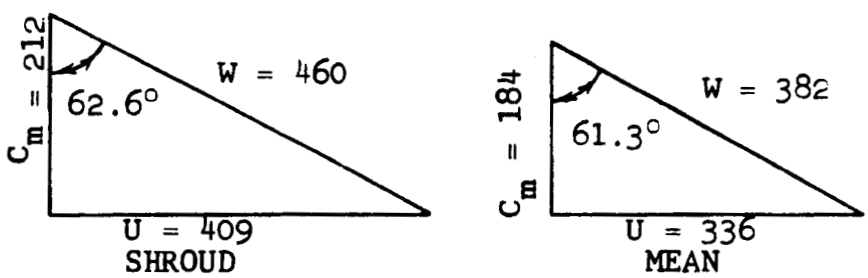
(h) Total temperatures at inlet and exit
(See Table 1)

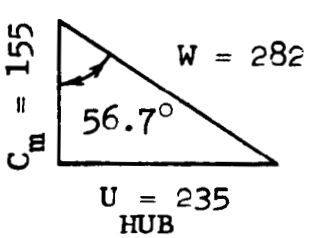
(i) Specific speed = 0.111

(j) Physical speed = 36,000 rpm

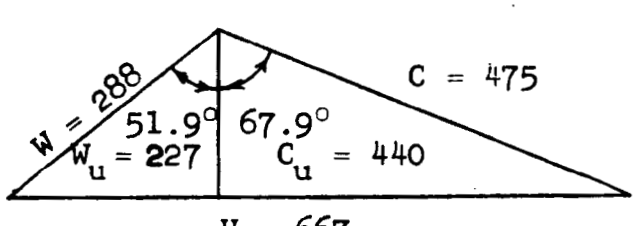
(k) Working fluid = XeHe mixture (molecular weight = 83.8)

(a) IMPELLER INLET VELOCITY TRIANGLES (INSIDE OF BLADE INCLUDING BLADE BLOCKAGE)





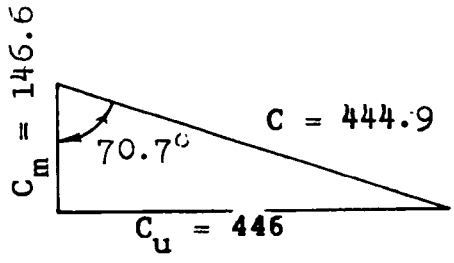
(b) IMPELLER EXIT VELOCITY TRIANGLES (MEAN VELOCITY INSIDE OF BLADE INCLUDING BLADE BLOCKAGE)



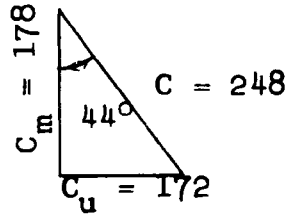
COMPRESSOR IMPELLER DIAGRAMS

FIGURE 2
APS-5269-R
Page 7

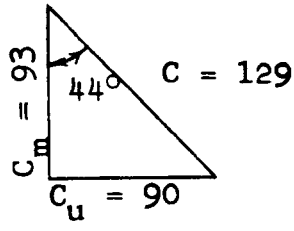
(a) DIFFUSER INLET (MEAN JUST UPSTREAM OF VANE)



(b) DIFFUSER EXIT (CORE VELOCITY INSIDE OF BLADE)



(c) SCROLL INLET (MEAN VELOCITY)



(d) SCROLL EXIT MEAN VELOCITY = 61 FT PER SEC.
YIELDING M_{EXIT} = 0.071

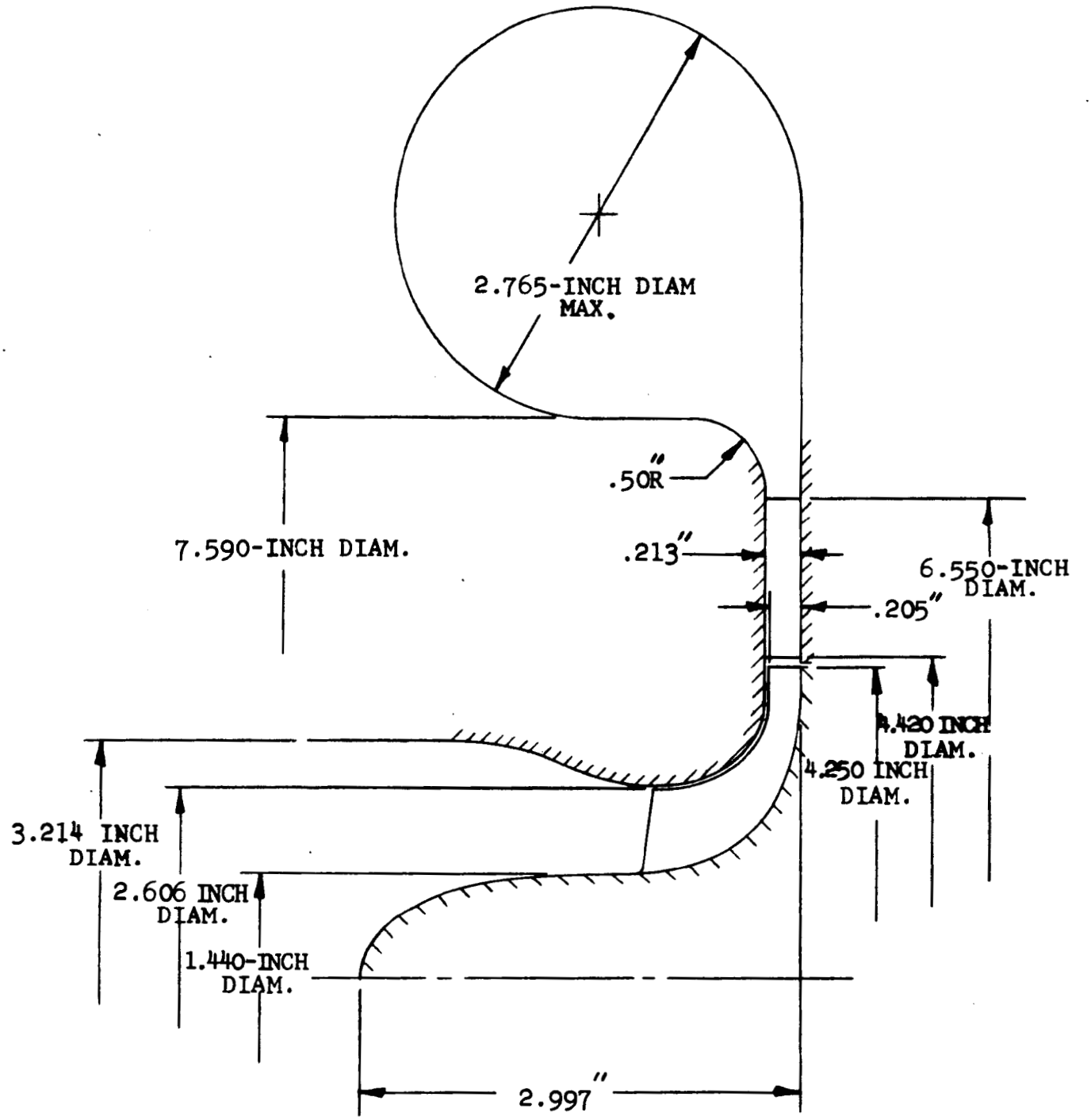
COMPRESSOR DIFFUSER AND SCROLL VELOCITY DIAGRAMS
FIGURE 3

TABLE I

PRESSURE, TEMPERATURE, AND EFFICIENCY

AT STATIONS THROUGH THE COMPRESSOR

	P_{Total} (psia)	P_{Static} (psia)	T_{Total} (^{o}F)	Efficiency Up To Location
Inlet (Outside Blade)	13.50	12.94	540.0	--
Impeller exit (Mean)	27.40	20.89	737.6	89.5
Diffuser Inlet (Core)	27.25	21.60	737.6	88.7
Diffuser Exit (Core)	27.25	25.40	737.6	--
Scroll Inlet (Mean)	25.81	25.39	737.6	81.0
Scroll Exit (Mean)	25.65	25.57	737.6	80.0



NASA BRU COMPRESSOR
ROTOR AND STATOR PHYSICAL DIMENSIONS

FIGURE 4

3.3 Compressor Wheel Stress Analysis

The BRU impeller, as discussed in Section 3.1, is an exact 0.514 scale-down of an existing impeller used extensively in a turboprop engine. The full sized impeller operates at a design speed of 41,700 rpm. Material density and scale factors applied to experimentally-determined blade stresses in the full-size wheel show that the blade stress levels in the BRU impeller are approximately 35 percent of those existing in the full-size wheel. The blade stress factor was determined as follows:

$$\text{Centrifugal stress} \propto (\text{density})\ (\text{radius})^2\ (\text{speed})^2$$

where: BRU wheel speed = 36,000 rpm
Full-size wheel speed = 41,700 rpm
BRU wheel material = 403 CRES (γ = 0.28 lb/in^3)
Full-size wheel material = titanium (δ = 0.16 lb/in^3)

Hence:

$$\text{Centrifugal blade stress for BRU impeller} = \left(\frac{.28}{.16}\right)\ (.514)^2 \left(\frac{36,000}{41,700}\right)^2$$

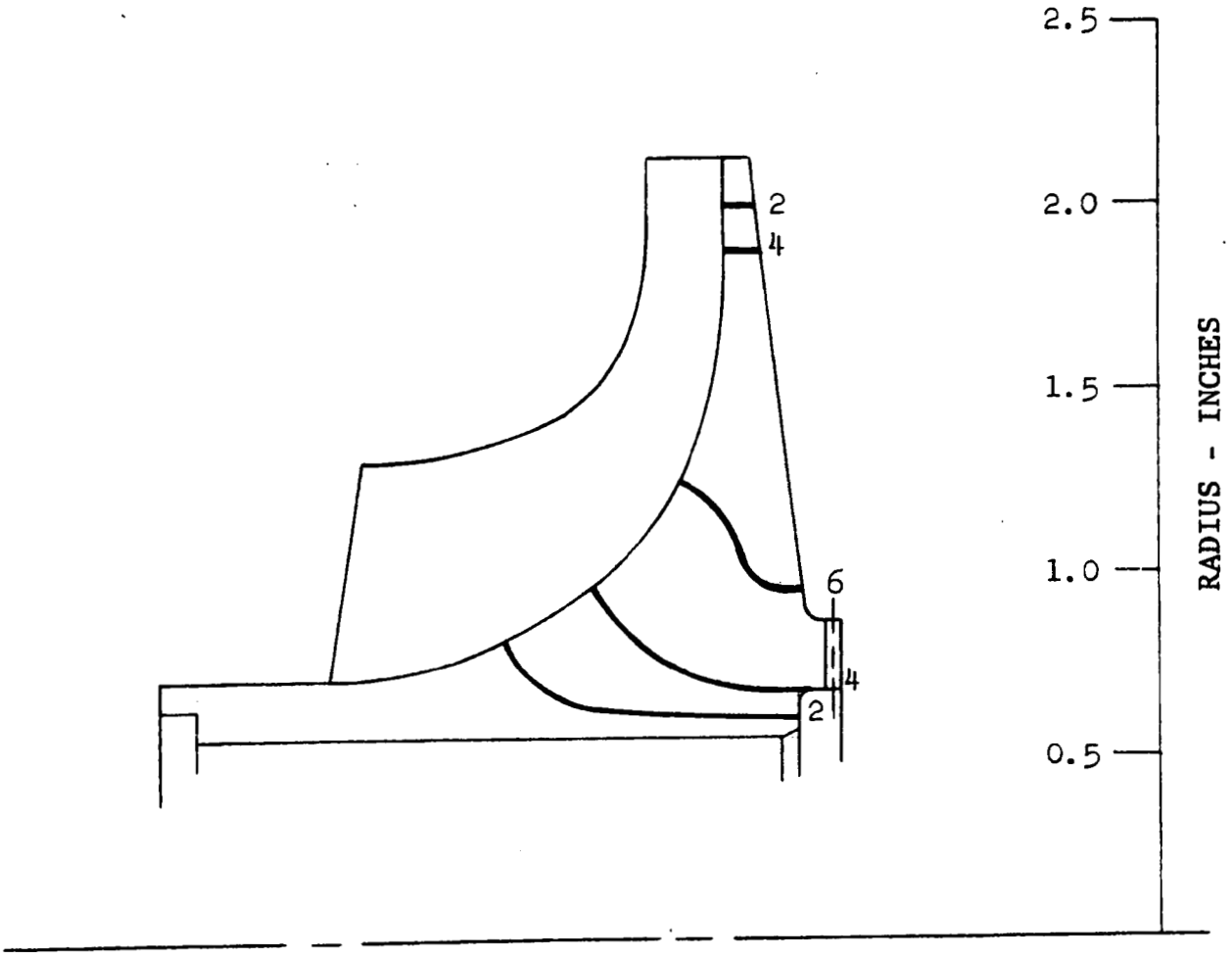
$$= 0.344 \times \text{Centrifugal blade stress for full-size impeller}$$

Applying this factor to the experimentally determined blade stress values for the full-size impeller results in maximum values for the BRU impeller of 25,000 psi.

A stress analysis was performed on the BRU impeller to determine the centrifugal stresses in the wheel disk at its operating speed

of 36,000 rpm. Figures 5 & 6 present, graphically, the radial and tangential stresses expected in the disk.

Yielding of the disk may be expected at a minimum speed of 65,000 rpm and the minimum burst speed may be expected at 95,000 rpm. Since creep of the 403 CRES wheel material is negligable at the temperatures and stress levels encountered in this application, the BRU compressor wheel may be considered essentially an infinite-life wheel.

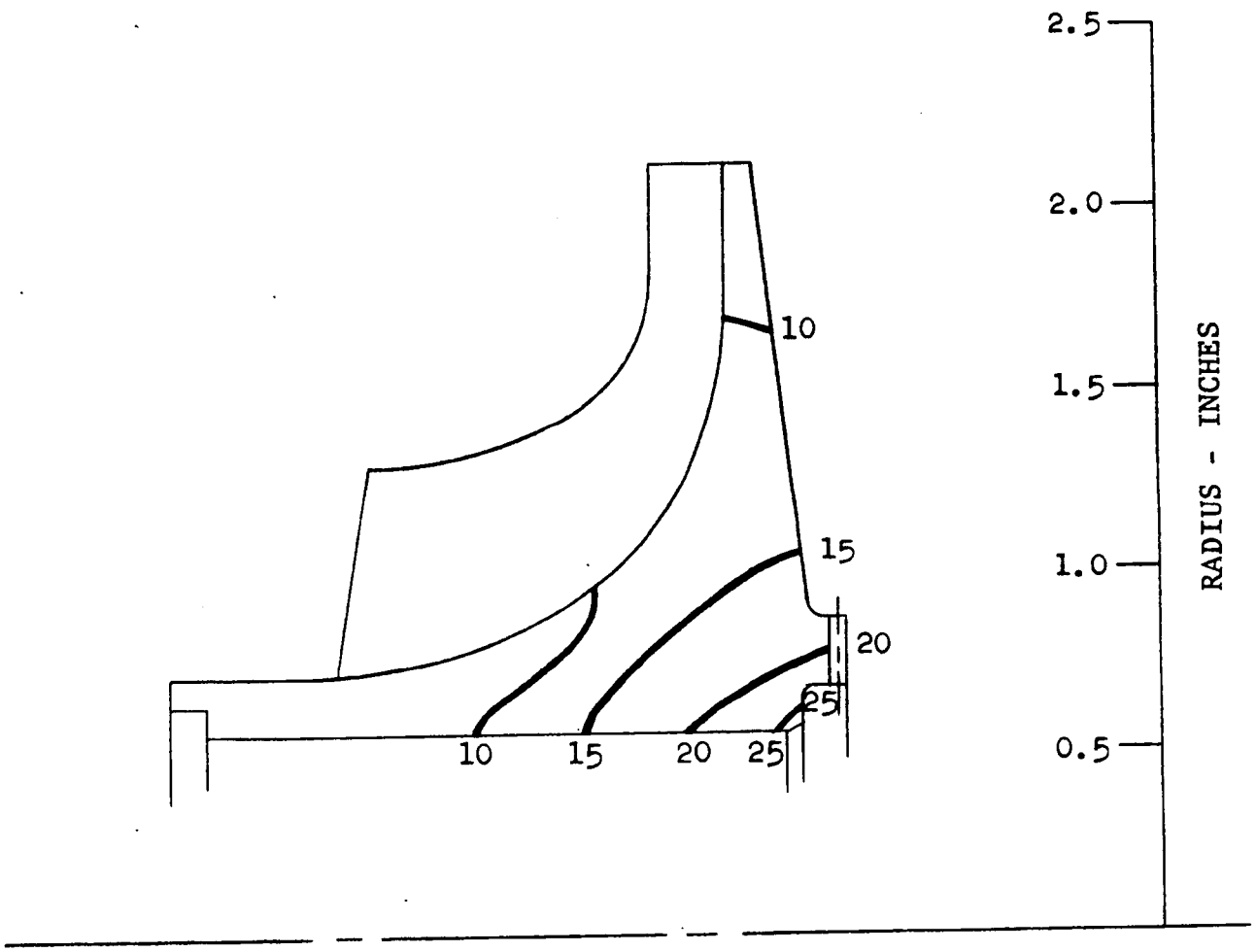


NOTES:

1. OPERATING SPEED = 36,000 RPM
2. MATERIAL = 403 CRES
3. ALL STRESSES IN KSI

NASA BRU COMPRESSOR IMPELLER
RADIAL STRESS DISTRIBUTION

FIGURE 5



NOTES:

1. OPERATING SPEED = 36,000 RPM
2. MATERIAL = 403 CRES
3. ALL STRESSES IN KSI
4. AVERAGE TANGENTIAL STRESS = 12,750 PSI

NASA BRU COMPRESSOR IMPELLER
TANGENTIAL STRESS DISTRIBUTION

FIGURE 6

3.4 Critical-Speed Analysis

In order to perform a critical-speed analysis for the compressor research package, the operating speed range for performance testing had to be determined. The desired speed range for the package is set forth in Table 2 . Selection of the speed range was coordinated with the cognizant personnel at the NASA-Lewis Research Center.

The elastic and mass model of the rotating assemblies used in the critical-speed analysis is shown in Figure 7 As can be noted, the balanced flexible coupling was included in the elastic and mass model. In addition, the Contractor-selected drive turbine, that was used for the acceptance testing of the research package was included to determine whether or not the flexible coupling arrangement would significantly influence the rigid-body critical speeds of the research package. The critical speeds of the compressor package rotating assembly, plotted as a function of bearing resilient-mount spring rates, are shown in Figure 8 for the case of equal spring rate mounts at both bearings. Figure 8 shows that the use of 30,000 ppi resilient mounts at each bearing will allow the compressor research package to operate over the range of 25,550 to 66,165 rpm without encountering rigid-body critical speeds. The bending mode critical is shown to be approximately 74,000 rpm. It should be noted that the drive turbine system critical speed (first system critical) is very low and does not influence the critical speeds of the compressor package. Bearing loads for the anticipated operating range (25,550 to 66,165 rpm) are plotted as a function of speed in Figure 9 for an assumed rotor c.g. eccentricity of 0.0002 inch.

TABLE 2

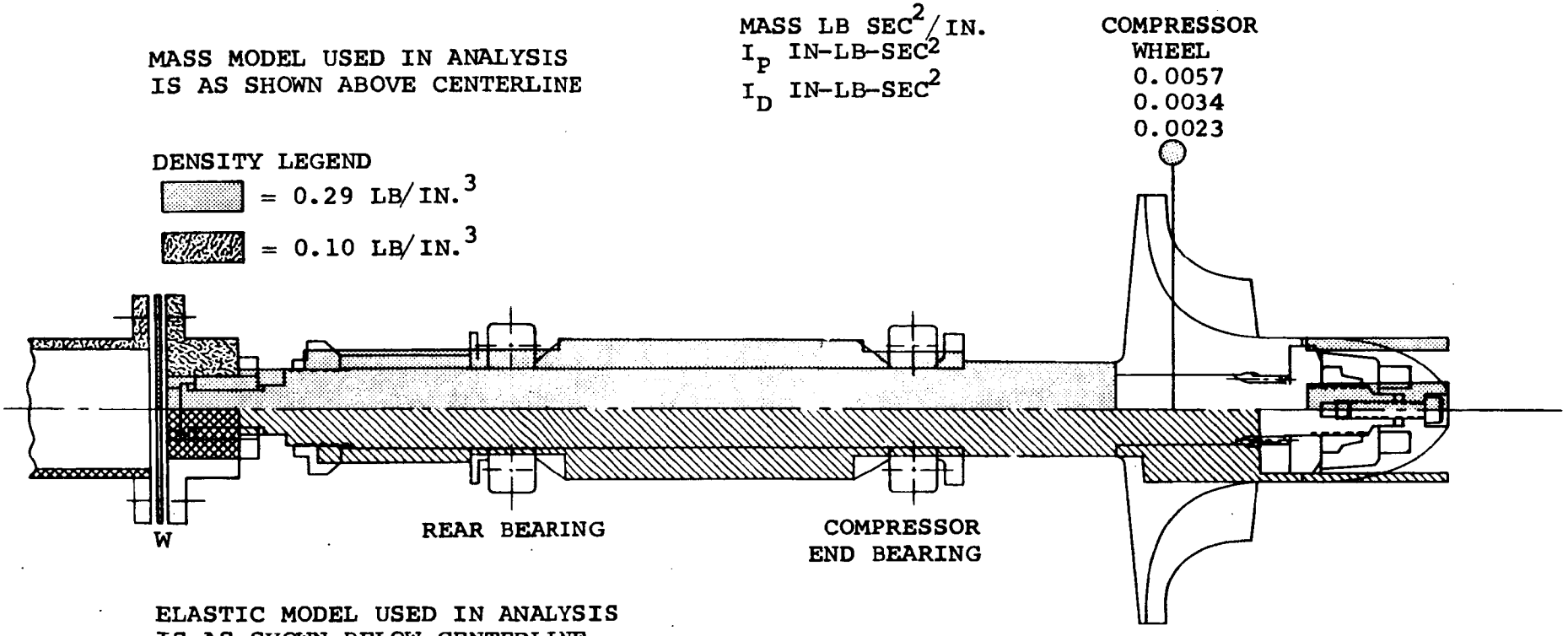
COMPRESSOR RESEARCH PACKAGE
OPERATING SPEED RANGE

Compressor:

Test Fluid	Percent Operating Speed 50	100
Argon (60°F inlet)	25,550 rpm	51,100 rpm
Air (60°F inlet)	30,075 rpm	60,150 rpm

Overspeed condition - 110 percent of 60,150 = 66,165 rpm
DESIGN SPEED RANGE = 25,500 - 66,165 rpm

NOTE: Testing with Helium-Xenon Gas Mixture is not a requirement.



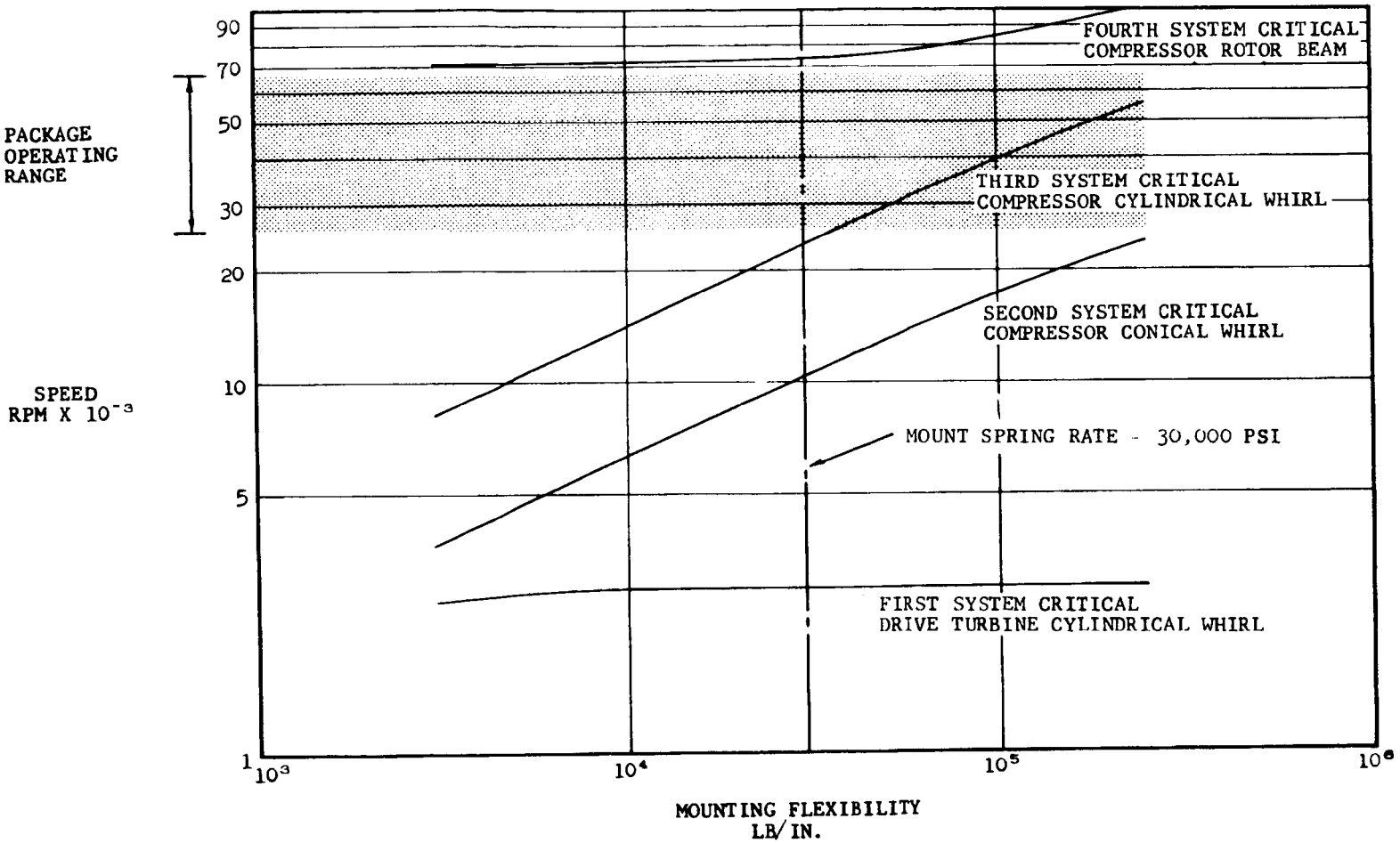
NOTES:

(1) DRIVE TURBINE MOUNTED ON FLEXIBLE MOUNTS WITH 1500 LB/IN. SPRING RATES.

(2) THE MOMENT TRANSMITTED THROUGH THE "WAFERS" WAS ASSUMED NEGLIGIBLE. IN ESSENCE, A PINNED-JOINT WAS ASSUMED AT EACH END OF THE FLEXIBLE COUPLING.

SYSTEM USED IN CRITICAL SPEED
BEARING LOAD ANALYSIS OF THE
BRU COMPRESSOR RESEARCH PACKAGE

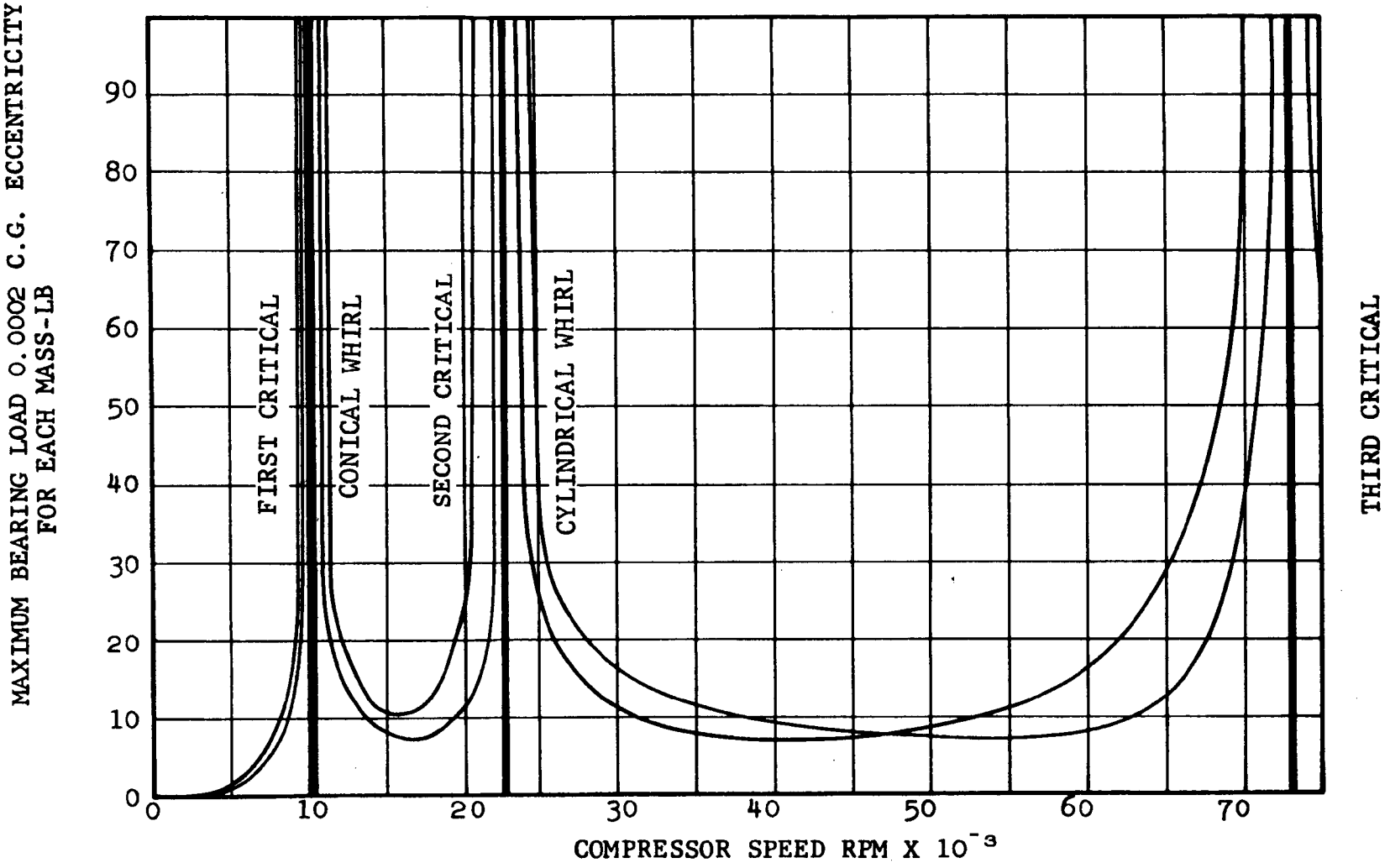
FIGURE 7



BRU COMPRESSOR RESEARCH PACKAGE
CRITICAL SPEEDS AS A FUNCTION
OF MOUNTING FLEXIBILITY
FOR BOTH MOUNTS EQUAL

NOTES: (1) REF: FIGURE 7
(2) EQUAL MOUNTINGS ON COMPRESSOR ROTOR

FIGURE 8



NOTES:
1. REF. FIGURE 8
2. BOTH BEARINGS FLEXIBLY MOUNTED
   $K = 3\ (10)^4$ LB/PER INCH

BEARING LOADS FOR BRU
COMPRESSOR RESEARCH PACKAGE

FIGURE 9

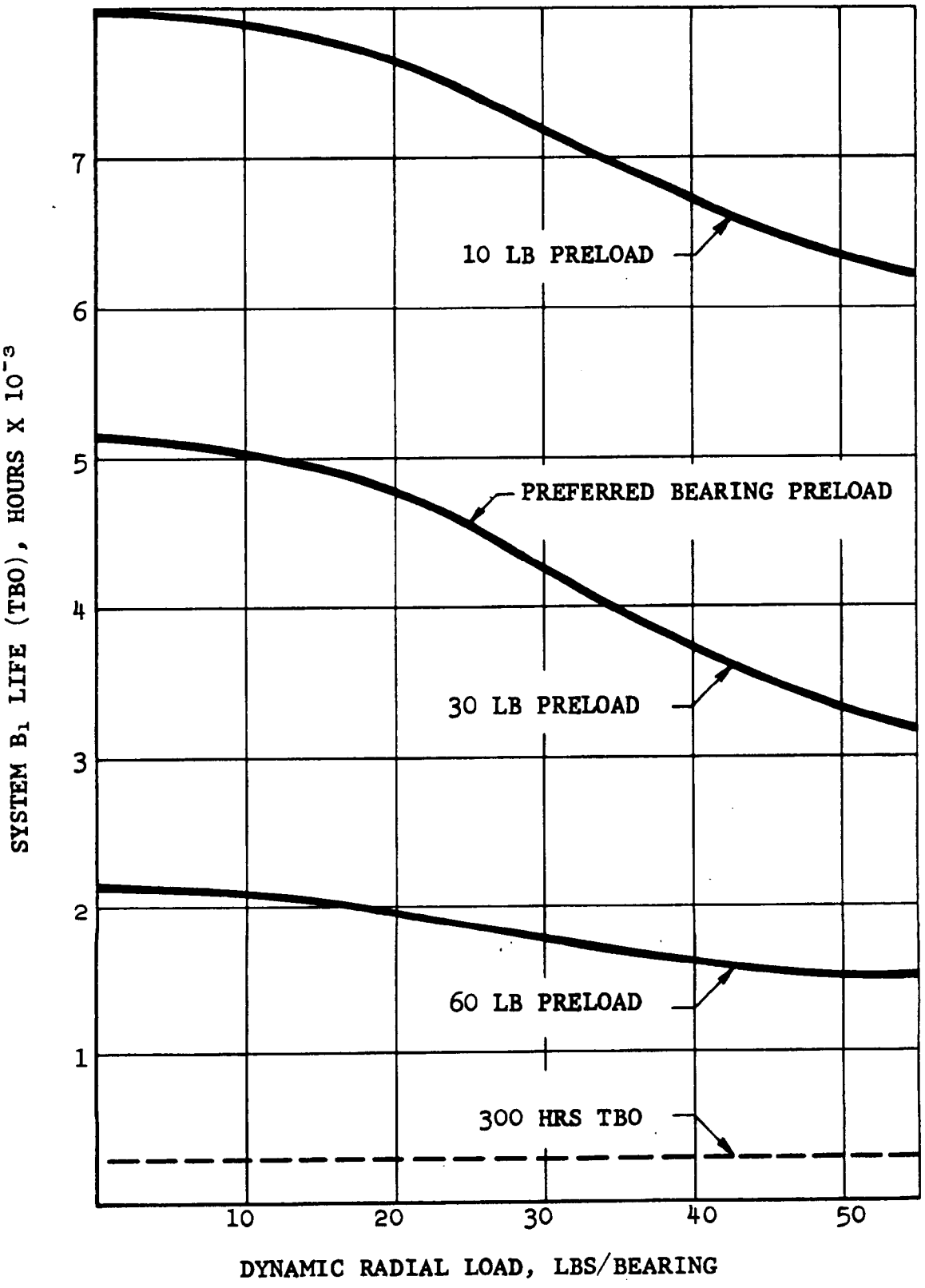
GARRETT
AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

3.5 Bearing and Seal Design Data and Drawings

The angular-contact rolling-element bearing selected as a result of a digital computer program optimization for the research package should adequately meet the design objective of a time-between-overhaul (TBO) of 300 hours minimum when using air-oil mist lubrication (MIL-L-7808). The major characteristics of the chosen bearing (Part 358500) are:

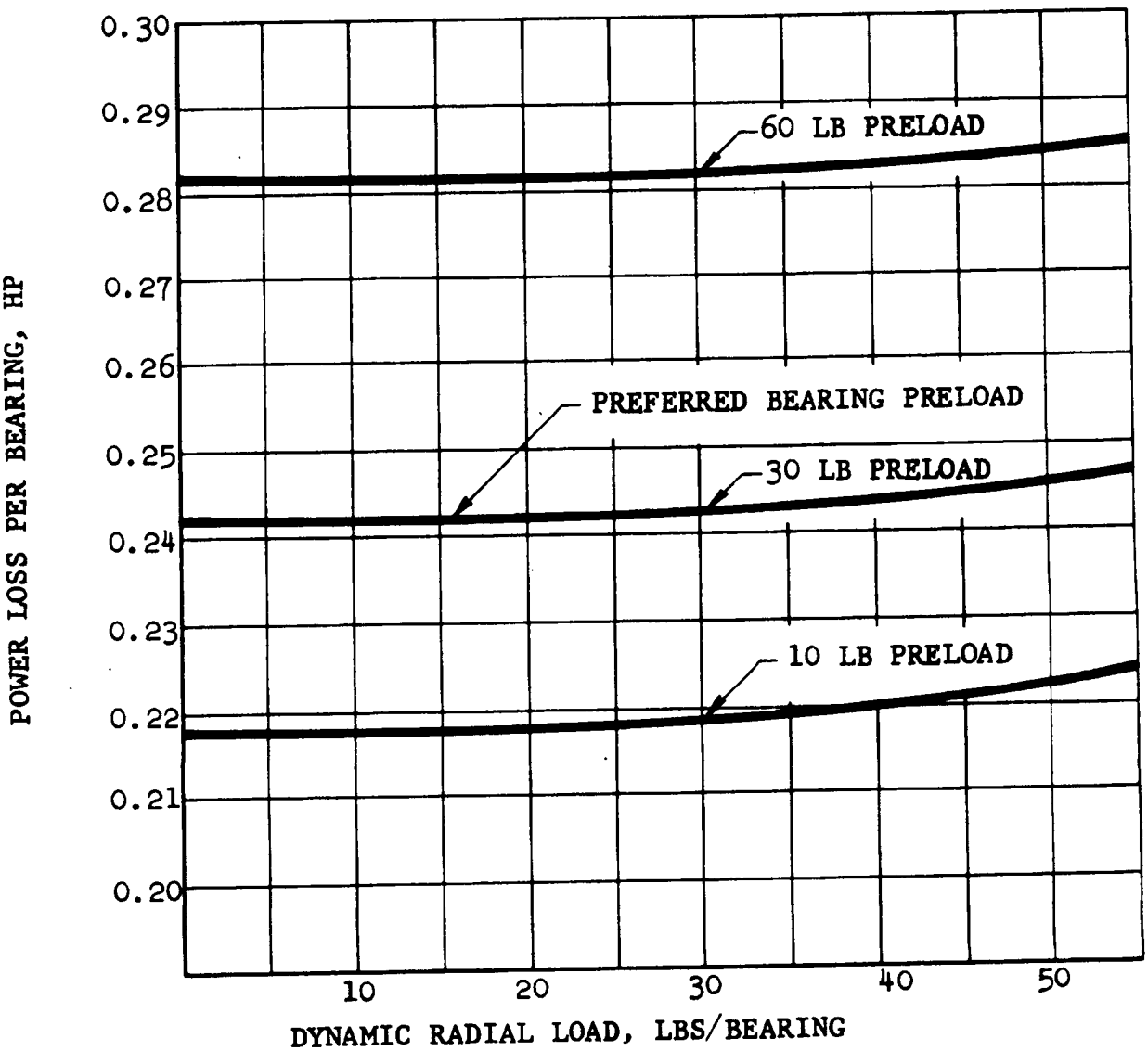
Bore diameter	20 mm
Outside diameter	42 mm
Width	12 mm
Number of balls	11
Ball diameter	9/32 inch
Inner-race curvature	52 to 53 percent of ball diameter
Outer-race curvature	52 to 53 percent of ball diameter
Contact angle	16 degrees
Ring and ball material	Consumable-Electrode vacuum-melted M-50 tool steel
Separator material	Iron-silicon-bronze, silver-plated

The unidirection (1 "g") radial bearing loads and thrust loads assumed for the analysis are shown in Table 3. The predicted bearing system life, B_1, for preloads of 10, 30, and 60 pounds for the compressor is shown in Figure 10. The predicted power loss per bearing for preloads of 10, 30, and 60 pounds for the compressor package is plotted in Figure 11. Representative package speeds, bearing loads, and predicted system B_1 life for the package is presented in Table 4. It is evident that the TBO design objective (300 hours minimum) can be easily met. The bearing configuration and material requirements are shown in Drawing 358500.



BEARING SYSTEM LIFE B_1
NASA BRU COMPRESSOR RESEARCH PACKAGE

FIGURE 10

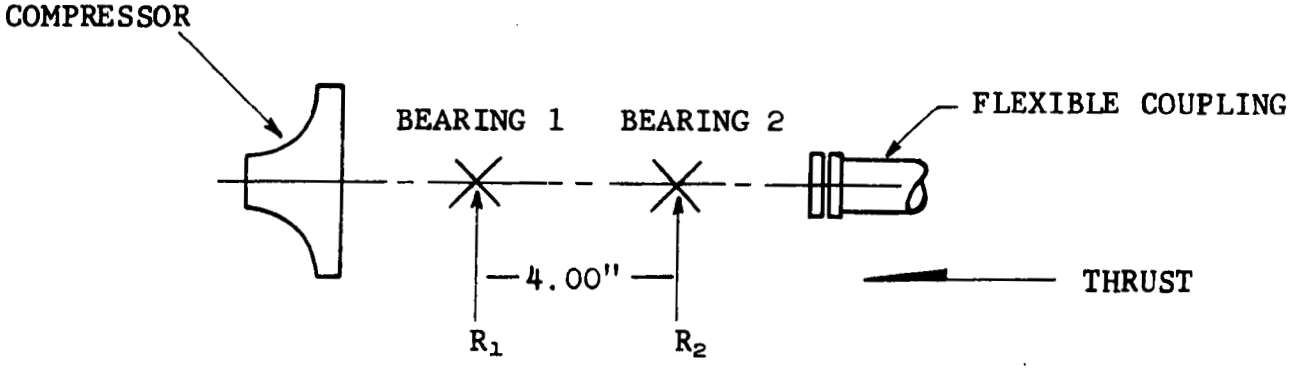


BEARING POWER LOSS FOR NASA BRU
COMPRESSOR RESEARCH PACKAGE BEARING

FIGURE 11

TABLE 3

UNIDIRECTIONAL BEARING LOADS ASSUMED FOR BEARING ANALYSIS, COMPRESSOR RESEARCH PACKAGE



NOTE: Bearing 2 takes thrust loads in the direction shown.

	R_1 (lbs)	R_2 (lbs)	Thrust (lbs)
Compressor Package	5.1	0.5	5

TABLE 4

COMPRESSOR RESEARCH PACKAGE BEARING SYSTEM B_1 LIFE (TBO)

Compressor (30 pounds being preload):

Speed (rpm)	Max. Bearing Load (lbs)	B_1 Life (Hours)
25,550	30	4,250
51,100	9	5,050
66,165	33	4,100

The carbon-face contact seal for the compressor is shown on Drawing 699683. Five vendors indicated their desire to participate in this program, three of whom were selected by the Contractor as being approved. The seal designs proposed by each of the three vendors were quite similar (standard O-ring configuration with wave washer spring loading). The internal configuration of the seal design allows for a constant pressure differential or direction of the pressure differential. The only face pressure incurred will result from the spring loading and O-ring drag. Thus, a very wide range of compressor wheel back-face pressures can be readily accommodated without seal carbon-face leakage or destruction.

3.6 Compressor Instrumentation

The compressor research package has a full compliment of static pressure instrumentation and provisions for the addition by the NASA, of total pressure and temperature instrumentation to assist in the aerodynamic performance evaluation of the compressor. The following is a list of the instrumentation and the provisions therefore as installed on the compressor research package:

(a) Inlet

(1) Three (3) static pressure taps in the same plane 120° apart. The bosses are machined with 1/8-inch pipe threads and a 0.030-inch diameter static pressure tap hole.

(2) Three (3) bosses for total pressure taps, 0.5-inch downstream of the static pressure taps and rotated 60° to the static taps and 120° apart. The bosses are machined with 1/8-inch threads.

(b) Rotor

(1) Three (3) sets of five static pressure taps along the rotor leading edge section of the rotor shroud set 120° apart.

(2) One (1) set of three (3) equally spaced machined bosses located axially at the rotor tip for blade clearance probes.

(c) Diffuser

(1) Vaneless section - Three (3) static pressure taps equally spaced on the rotor shroud located between rotor outlet and vaned diffuser inlet.

(2) Vaned section - Two (2) sets of five (5) static pressure taps each along the diffuser mid-channel streamline, one (1) set on each side of a diffuser passage.

(d) Scroll exit

(1) Four (4) static pressure taps in the same plane, 90° apart. The bosses are machined with 1/8-inch pipe threads and a 0.030-inch diameter static pressure tap hole.

(2) Four (4) bosses for total pressure taps, 0.5-inch downstream of the static taps, rotated 45° to the static taps and 90° apart. The bosses are machined with 1/8-inch pipe threads.

e. Bearings

(1) Three (3) C.A. thermocouples on each bearing

f. Shaft speed

(1) Three (3) Electro Products (No. 3016) shaft speed pickups spaced 45° apart.

4.0 GENERAL UNIT DESCRIPTION

The dimensional outline of the compressor research package is shown in Drawing 699680. This drawing also defines the interfaces between (a) the end of the impeller shaft machined to mate with the drive coupling, Drawing 699667 (NASA Drawing CC844330), (b) the bolt flanges at the compressor inlet and discharge to permit attachment to adaptor flanges, Drawings 699767 and 699768 and (c) the mating electrical connectors (temperature, speed and power) and pipe fittings. General operating conditions for the unit are also specified.

A cross-sectional view of the compressor research package is shown in Assembly Drawing (699681). The unit consists of the impeller assembly (Item 8) mounted in the main housing (Item 1) on two antifriction bearings (Item 6, also Drawing 358500). Both bearings are resiliently mounted with a spring rate of 30,000 pounds per inch using the bearing mount assembly (Item 5). This spring rate was chosen so that the operating speed range would be between a low second critical and a very high third critical; a coil spring (Item 30) provides 30 pounds of axial preload on the bearings. An oil jet (Item 27) supplies pressurized, air-oil mist to each bearing.

Labyrinth type seals are provided at each end of the housing. The impeller end seal has a purge chamber located in the middle of the seal. The impeller end is also equipped with a carbon-face type oil seal (Item 9, also Drawing 699683).

The compressor scroll (Items 24, 25, and 26) is attached to the main housing by a bolted flange. Shimming to obtain the desired compressor-wheel-shroud-face clearance is accomplished at this flange by providing a shim of predetermined thickness between the housing and the scroll flange. A design value of the clearance was established at 0.007-0.009 inch. Sealing at this shim is accomplished with the O-rings (NAS 1593-174). A rigid mounting base (Item 2) provides for mounting the compressor research package on a test stand bed-plate.

5.0 COMPRESSOR RESEARCH PACKAGE ACCEPTANCE TESTING

The compressor research package acceptance test was performed at the AiResearch Manufacturing Company, Phoenix, Arizona on August 15, 1967. All testing was conducted at the Phoenix Division laboratory facility and was witnessed by a representative of the NASA.

The acceptance test setup consisted of three basic components mounted on an aluminum fixture (see Figures 12, 13, and 14) as follows:

(a) AiResearch Constant Speed Drive Starter (CSDS) turbine

(b) Coupling (NASA Drawing CC844330)

(c) Compressor Research Package

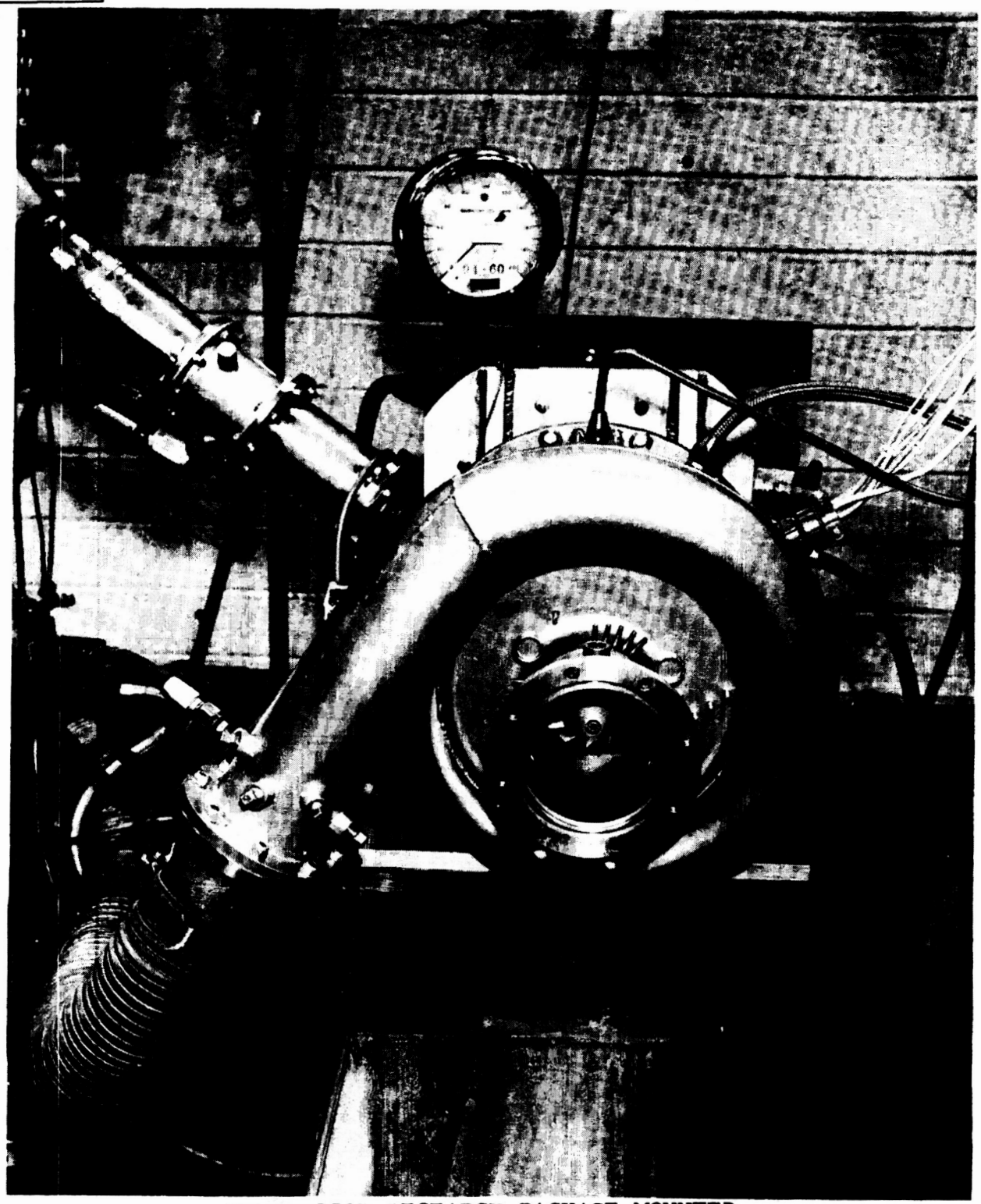
During the test the CSDS turbine, supplied with plant compressed air energy, was used to drive the compressor package through the 699667 coupling. Air-oil mist lubrication for the package was furnished by a calibrated Norgren oiler.

The acceptance test was conducted as follows: A critical speed of the system to 51,200 rpm (100 percent design speed). The system was then stabilized at design speed for the required 30 minutes, during which time unit speed, vibration, and bearing temperatures were manually recorded at five minute intervals.

Following this 30 minute cycle, the speed was increased to 61,400 rpm (120 percent design speed) for 10 minutes. The

acceptance test was then complete and the system was shut down.

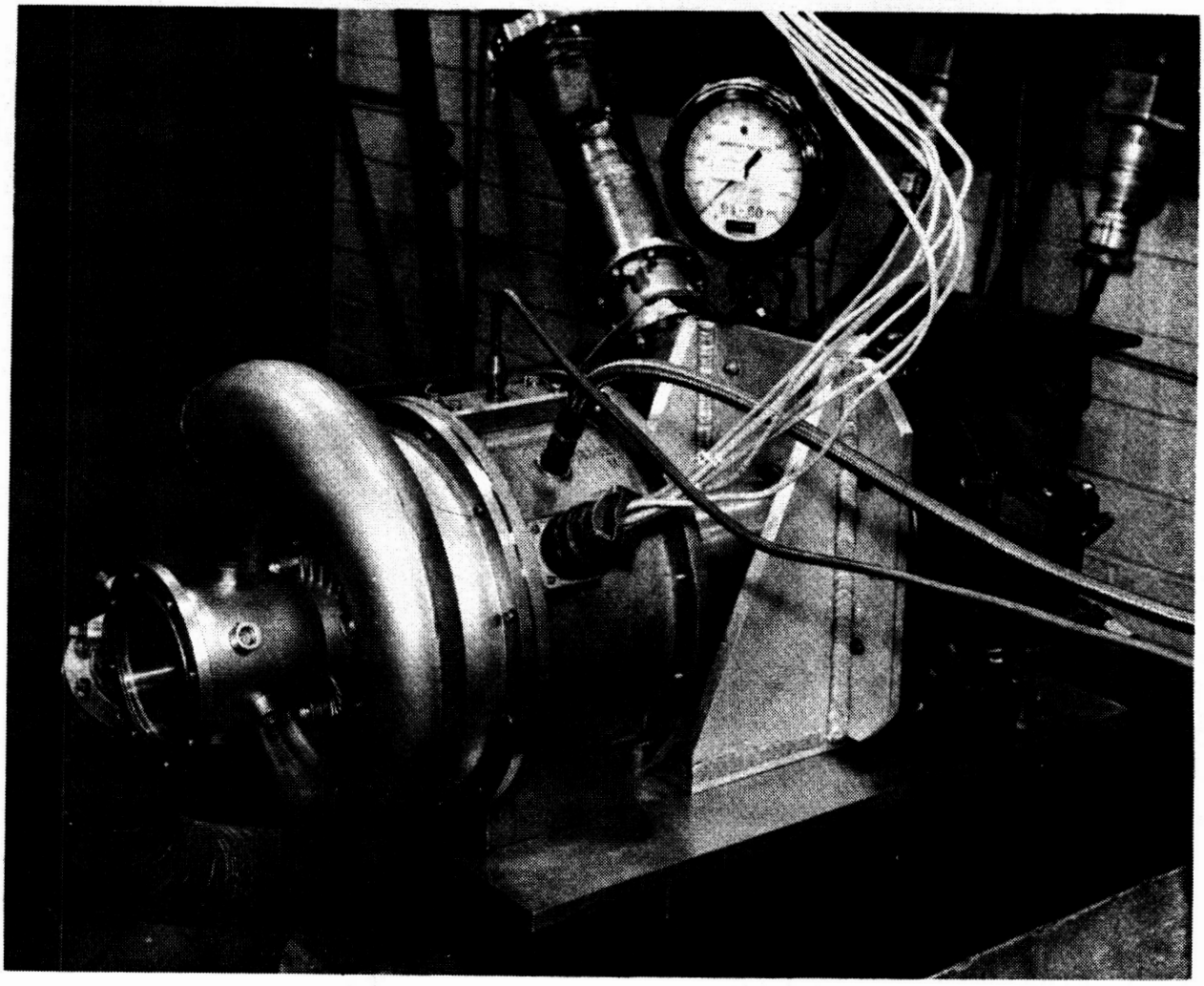
Acceptance test data, including assembly instructions, parts list, delivery spares and the unit build history have been delivered to the NASA Lewis Research Center in a separate document in accordance with contract requirements.



COMPRESSOR RESEARCH PACKAGE MOUNTED
IN ACCEPTANCE TEST RIG-FRONT VIEW

FIGURE 12

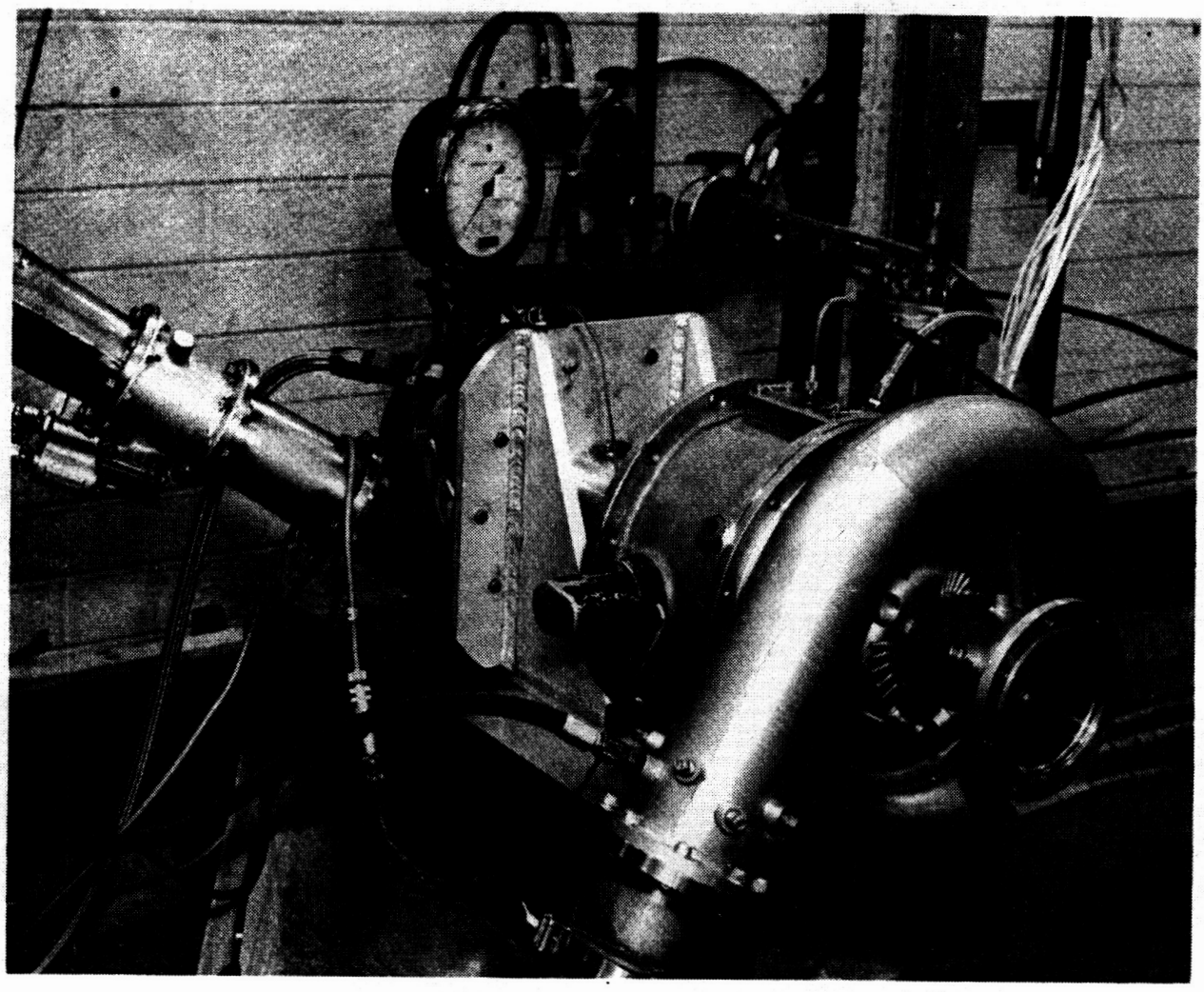
MP-17353



COMPRESSOR RESEARCH PACKAGE MOUNTED IN
ACCEPTANCE TEST RIG - LEFT SIDE VIEW

FIGURE 13

MP-17 752

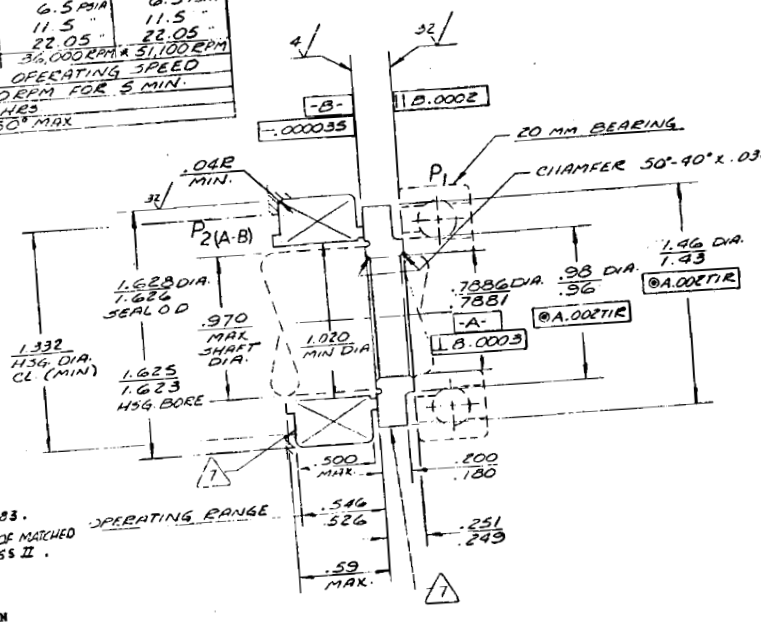


COMPRESSOR RESEARCH PACKAGE MOUNTED IN
ACCEPTANCE TEST RIG - RIGHT SIDE VIEW

FIGURE 14

MP-17354

PART NO.	OPERATING CONDITIONS	P_1	$P_{2\text{-}A}$	$P_{2\text{-}B}$
699683-1	MEDIUM	AIR-OIL MIST (MIL-L-7808)	HELIUM-XENON	ARGON
		14.7 PSIA	6.5 PSIA	6.5 PSIA
		14.7 "	11.5 "	11.5 "
		14.7 "	22.05 "	22.05 "
	SPEED		36,000 RPM * 51,100 RPM	
	* NOTE: NORMAL OPERATING SPEED			
	OVERSPEED — 61,320 RPM FOR 5 MIN.			
	LIFE — 300 HRS			
	TEMPERATURE — 350° MAX			



SOURCE CONTROL DRAWING

11. THESE PARTS TO BE MANUFACTURED, INSPECTED, STOCKED AND SOLD AS REPLACEMENT PARTS IN MATCHED SETS ONLY.
10. SHAFT MATERIAL: 4340
9. SEAL HOUSING MATERIAL: 300 SERIES STAINLESS
8. PROCUREMENT SOURCE(S) PER ASL 699683.
7. AIRESEARCH PART NUMBER & SERIAL NUMBER OF MATCHED SET HERE PER AIRESEARCH SPEC. 5014, CLASS II.
6. ALL DESIGN AND PART NUMBER CHANGES REQUIRE PRIOR AIRESEARCH APPROVAL.
5. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREON IS APPROVED BY AIRESEARCH MANUFACTURING COMPANY, PHOENIX, ARIZONA FOR USE IN THE APPLICATION(S) SPECIFIED HEREON. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY AIRESEARCH MANUFACTURING COMPANY OR BY THE GOVERNMENT PROCURING ACTIVITY.
4. DRAWING REVISIONS FOR SUBSTITUTE ITEMS SHALL NOT BE MADE WITHOUT PRIOR APPROVAL BY AIRESEARCH MANUFACTURING COMPANY.
3. IDENTIFY PACKAGING WITH AIRESEARCH PART NUMBER.
2. PARTS PROCURED BY VENDOR PART NUMBER SHALL BE PROCURED IN ACCORDANCE WITH THIS AIRESEARCH SOURCE CONTROL DRAWING.
1. DETAILS OF DESIGN AND CONSTRUCTION OTHER THAN SHOWN SHALL BE AT OPTION OF VENDOR.

"See tab block (upper left corner) for PART NUMBER

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

QUANTITY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION	ZONE
		← ASSY		LIST OF MATERIAL			

CRITICAL ITEM

UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC-5535, STANDARD DRAWING INTERPRETATIONS.

		SIGNATURES	DATES
N-1 699671-1	699670-1	DFT	
REQD NEXT ASSY	USED ON	CHK B.G.H.	1-11-67
HEAT TREATMENT	PROCESS	MFG	
HARDNESS AND SPEC	NAME AND SPEC	MATL	
		STRESS	
		AERO	
		APPD	1-13-67
		APPD	
		DESIGN ACTIVITY APPD	1-16-67
		OTHER ACTIVITY APPD	

AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

DWG TITLE: SEAL & ROTOR SET, MATCHED

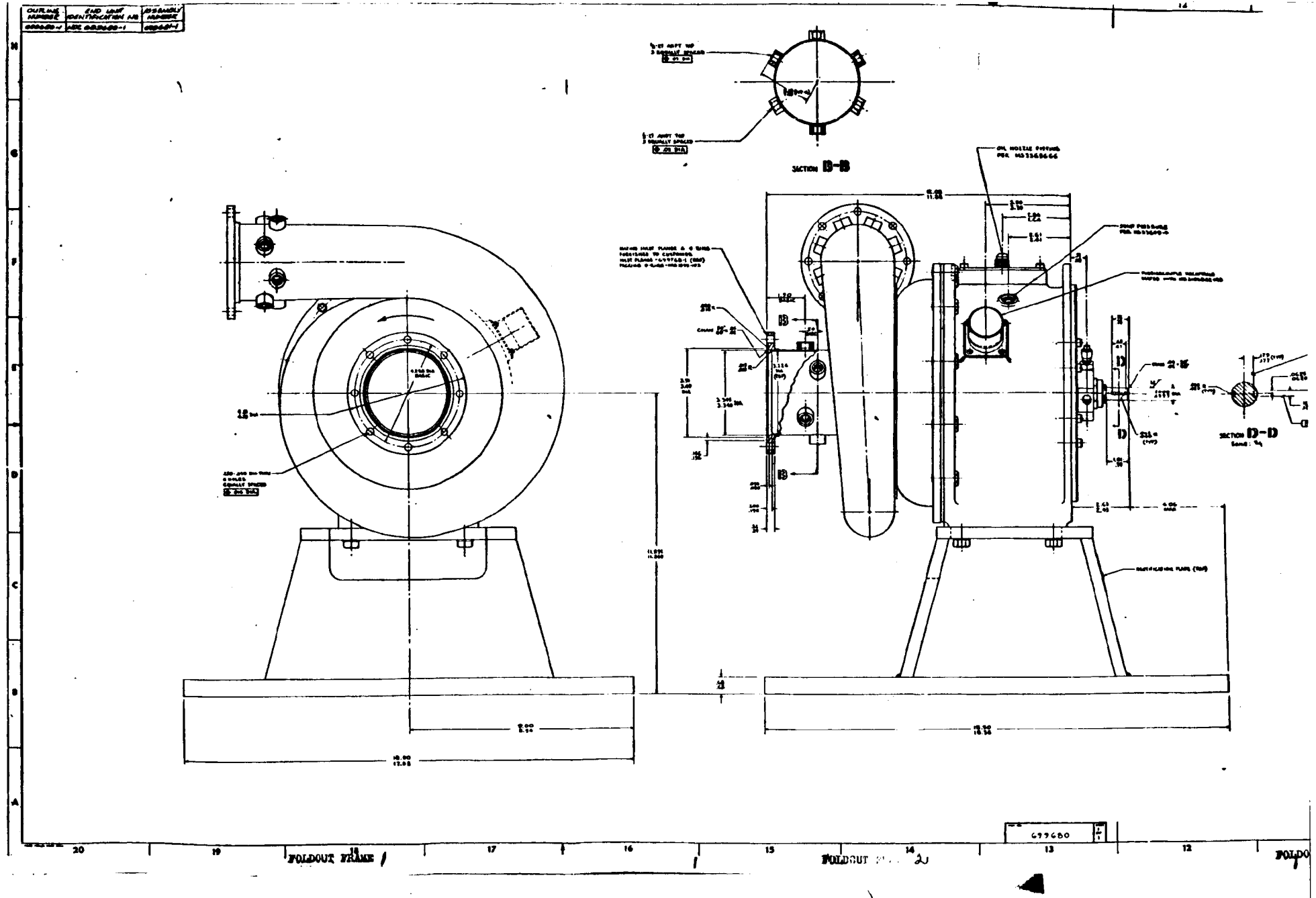
SIZE	CODE IDENT NO.	DWG NO.
C	99193	699683

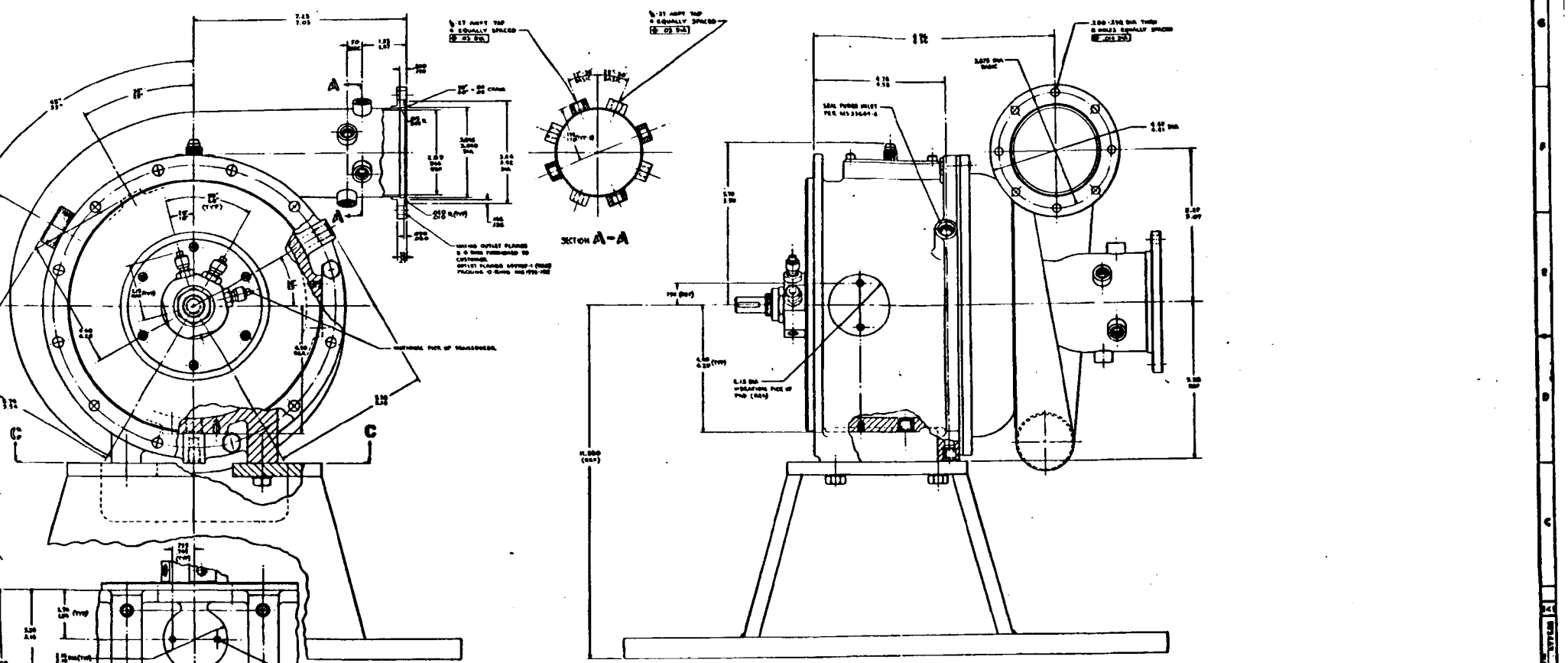
SCALE 2X | WT | SHEET 1 OF 1

FOLDOUT FRAME 2 1

699683

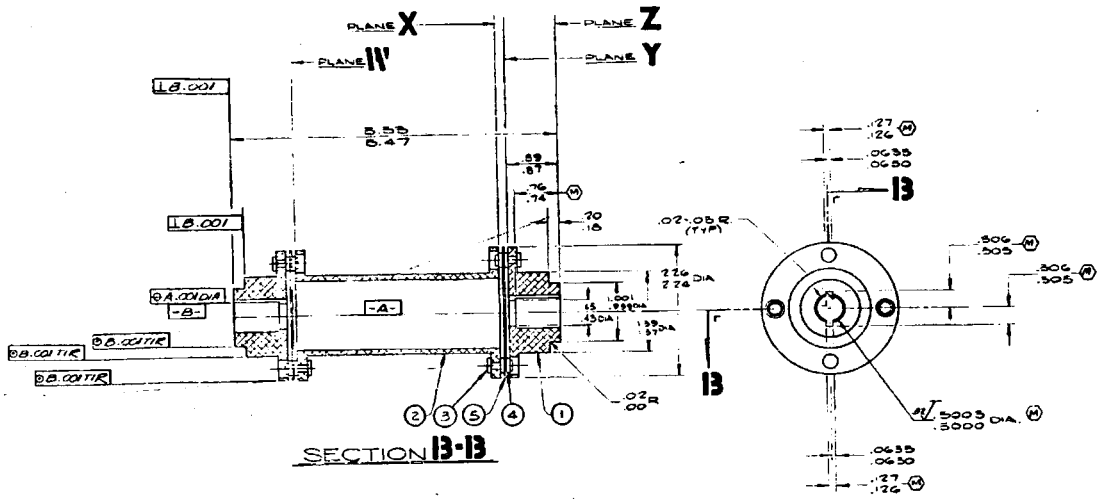
UT FRAME 1


SECTION B-B
SECTION D-D
699680
FOLDOUT FRAME 1
FOLDOUT FRAME 2


SECTION A-A
PARTIAL SECTION C-C
SEE THIS DRAWING (LAST SHEET) FOR OUTLINE AND IDENTIFICATION NUMBER
RESEARCH PACKAGE OUTLINE, COMPRESSOR
699680

PART NO
699667-1

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE	APP



13. POSIONAL AND GEOMETRIC TOLERANCE SYMBOLS PER MIL-STD-8 .

12. (C) DESIGNATES CRITICAL CHARACTERISTIC
(M) DESIGNATES MAJOR CHARACTERISTIC

(M)11. DYNAMIC BALANCE REQUIREMENTS:
11.1 BALANCING SPEED 8500 RPM MIN
11.2 A SINGLE ARBOR MAY BE BALANCED TO WITHIN .0028 OZ-IN AND HAVING DATUM 'B' LOCATING FITS CONCENTRIC TO THE ROTATING AXIS WITHIN .0001 TIR SHALL BE UTILIZED THROUGHOUT BALANCING PROCEDURE.
11.3 DYNAMICALLY BALANCE ITEMS INDIVIDUALLY AS INDICATED BELOW TO WITHIN .0028 OZ-IN. REMOVE METAL FROM FLANGES 3 & 4 IF NECESSARY.
11.4 COMPLETELY ASSEMBLY COUPLING & DYNAMICALLY BALANCE ASSEMBLY ABOUT BORES DIA TO WITHIN .0028 OZ-IN. REMOVE METAL FROM FLANGES 3 & 4 IF NECESSARY.

10. NO SET SCREWS, ACCESS HOLES OR ANODIZE.
9. FINISH ALL OVER EXCEPT NOTED ▽.
8. DETAILS OF DESIGN AND CONSTRUCTION OTHER THAN SHOWN TO BE AT OPTION OF VENDOR.
7. PARTS PROCURED BY VENDOR PART NUMBER SHALL BE PROCURED IN ACCORDANCE WITH THIS AIRESEARCH SOURCE CONTROL DRAWING.
6. IDENTIFY PACKAGING WITH AIRESEARCH PART NUMBER.
5. DRAWING REVISIONS FOR SUBSTITUTE ITEMS SHALL NOT BE MADE WITHOUT PRIOR AIRESEARCH APPROVAL.
4. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDORS LISTED HEREON IS APPROVED BY AIRESEARCH MANUFACTURING CO OF PHOENIX, ARIZONA FOR USE IN THE APPLICATIONS SPECIFIED HEREON. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY AIRESEARCH MFG. CO. OR BY THE GOVERNMENT PROCURING ACTIVITY.
3. ALL DESIGN AND PART NUMBER CHANGES REQUIRE PRIOR AIRESEARCH APPROVAL.
2. APPLY AIRESEARCH PART NUMBER PER AIRESEARCH SPEC. MC5014 CL ▽ A.
1. PROCUREMENT SOURCES PER ASL 699667.

NOTES:

SEE TAB. BLOCK (UPPER LEFT CORNER) FOR PART NUMBER.

SOURCE CONTROL DRAWING

QUANTITY REQD	ITEM NO	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
		← ASSY				LIST OF MATERIAL
2	6	-19		DISC		BERYLLIUM COPPER QQ-C-533
1/2	4	-17		WASHER		BRASS QQ-B-626
0	3	-16		RIVET		BRASS QQ-B-626
1	2	-15		OUTER MEMBER		AL ALLOY AMS 4122/7075-T
2	1	699667-11		FLANGE		AL ALLOY AMS 4122/7075-T

1 (1)	699667-1	699667-1	3-21-67
1 (1)	699667-1	699667-1	5-1-67
1 (1)	699667-1	699667-1	5-1-67

RECD	NEXT ASSY	USED ON

HEAT TREATMENT	PROCESS
HARDNESS AND SPEC	NAME AND SPEC

SIGNATURES	DATES
DES	3-21-67
CHK	5-1-67
MATL	5-1-67
STRESS	5-1-67
ASSY	5-1-67
APPD	5-1-67
APPD	5-1-67
DESIGN ACTIVITY APPD	5-8-67
OTHER ACTIVITY APPD	

AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

DWG TITLE
COUPLING ASSEMBLY
DRIVE

SIZE	CODE IDENT NO	DWG NO
D	99193	699667

SCALE 1/1 | WT – | SHEET 1

UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC-5535, STANDARD DRAWING INTERPRETATIONS.

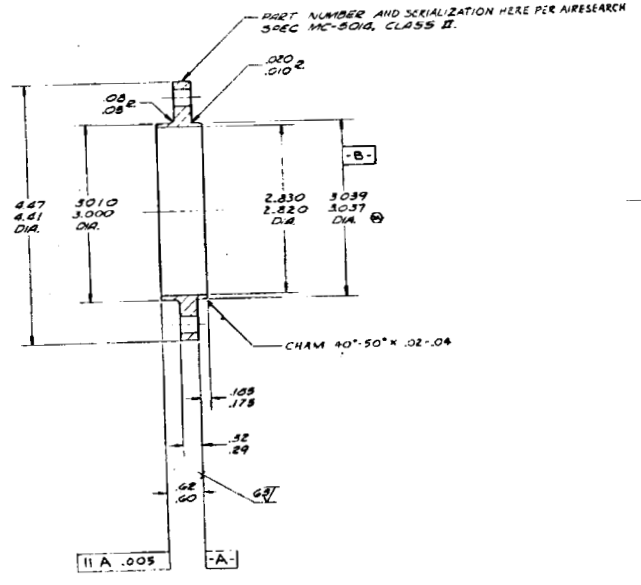
CRITICAL ITEM

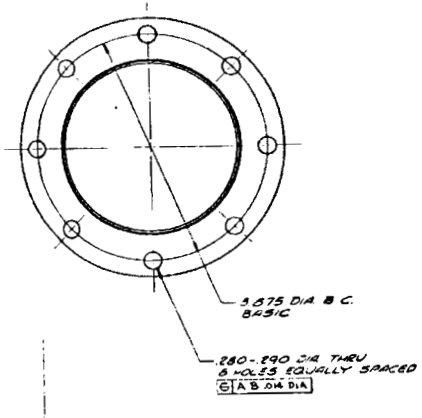
FOLDOUT FRAME 1

FOLDOUT FRAME 2

PART NUV362
699767-1

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE





SEE TAB. BLOCK (UPPER LEFT CORNER) FOR PART NUMBER.

QUANTITY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
		ASSY				347 CRES AMS5646M

LIST OF MATERIAL

SIGNATURES	DATES
DES	6-13-67
CHK	6-14-67
APP	6-14-67
MATL	6-14-67
STRESS	6-15-67
PROJ	
APPD	6-17-67
APPD	6-14-67
CUSTOMER APPD	6-19-67
OTHER ACTIVITY APPD	

AIRESEARCH MANUFACTURING COMPANY OF A DIVISION OF THE GARRETT CORPORATION PHOENIX, ARIZONA

UNIT TITLE: FLANGE, COMPRESSOR OUTLET

SIZE	CODE IDENT NO.	DWG NO.
D	99193	699767

SCALE 1/1 | WT | SHEET

REQD	NEXT ASSY	USED ON
1	FINAL	699767-1

HEAT TREATMENT: NOTED | PROCESS | HARDNESS AND SPEC | NAME AND SPEC

CRITICAL ITEM

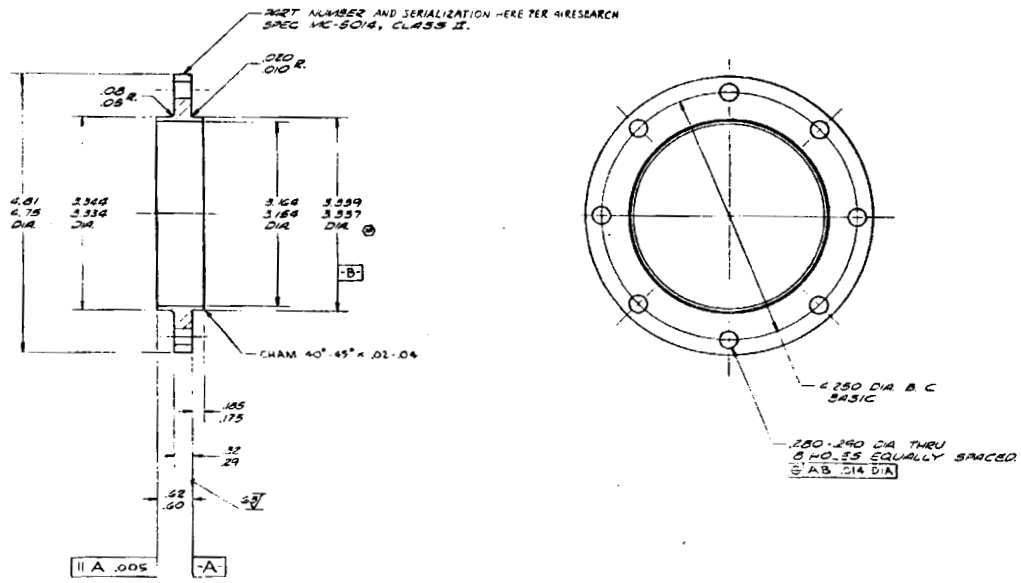
UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC 5515, STANDARD DRAWING INTERPRETATIONS.

4. FLUORESCENT INSPECT PER AMS 2645
3. (M) Designate Major Characteristics
2. SERIAL NUMBER CONTROL MUST BE MAINTAINED ON THIS PART THROUGHOUT MANUFACTURING AND ASSEMBLY CYCLES AND AFTER FINISH MACHINING. SERIAL NUMBERS SHALL BE APPLIED BY THE METHOD AND AT THE LOCATION SPECIFIED.
1. FINISH ALL OVER 125 OR AS NOTED.

FOLDOUT FRAME 2

PART NUMBER 699768-1

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE



SEE TAB. BLOCK (UPPER LEFT CORNER) FOR PART NUMBER.

4. FLUORESCENT PENETRANT INSPECT PER AMS 2645
3. Ⓜ Designate Major Characteristics
2. SERIAL NUMBER CONTROL MUST BE MAINTAINED ON THIS PART THROUGHOUT MANUFACTURING AND ASSEMBLY CYCLES AND AFTER FINISH MACHINING. SERIAL NUMBERS SHALL BE APPLIED BY THE METHOD AND AT THE LOCATION SPECIFIED.
1. FINISH ALL OVER 125 OR AS NOTED.

CRITICAL ITEM

UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC-5535, STANDARD DRAWING INTERPRETATIONS.

QUANTITY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
		← ASSY				347 CRES AMS5646 or 55

LIST OF MATERIAL

1 (-1) FINAL	699768-1	
REQD NEXT ASSY	USED ON	
HEAT TREATMENT	PROCESS	
HARDNESS AND SPEC	NAME AND SPEC	NOTED

SIGNATURES	DATES
DRAFT	2-20-67
CHK	4-14-67
ENGR	4-14-67
STRESS	11-14-67
APPD	1-16-67
APPD	4-17-67
APPD	4-17-67
DRAFTING RELEASE	4-17-67
OTHER ACTIVITY APPD	

AIRESEARCH MANUFACTURING COMPANY OF A DIVISION OF THE GARRETT CORPORATION PHOENIX, ARIZONA

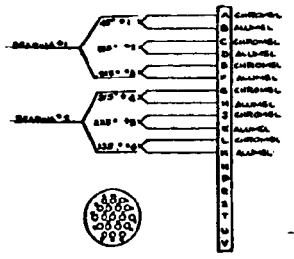
DWG TITLE: FLANGE, COMPRESSOR INLET

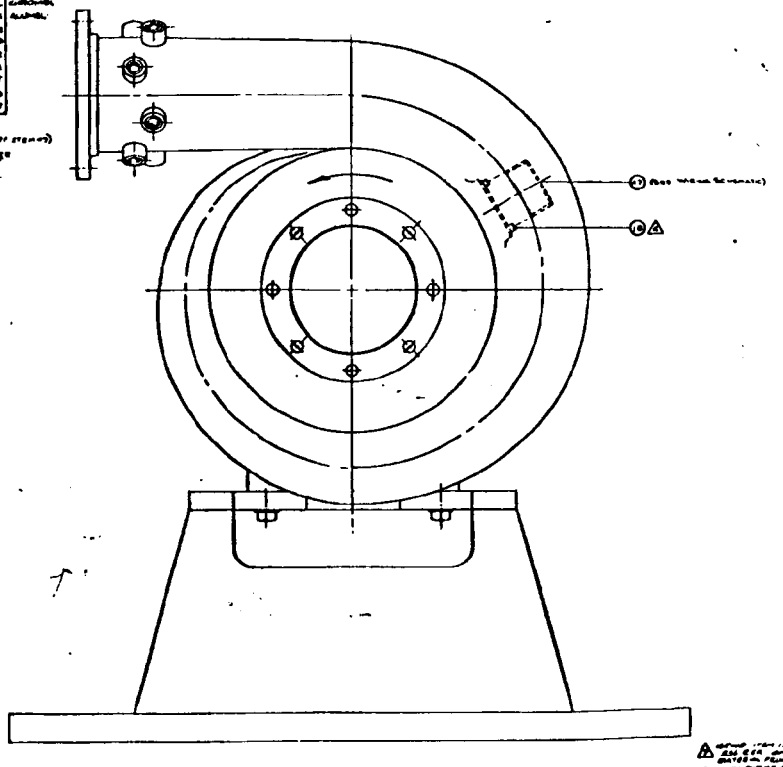
SIZE	CODE IDENT NO.	DWG NO.
D	99193	699768

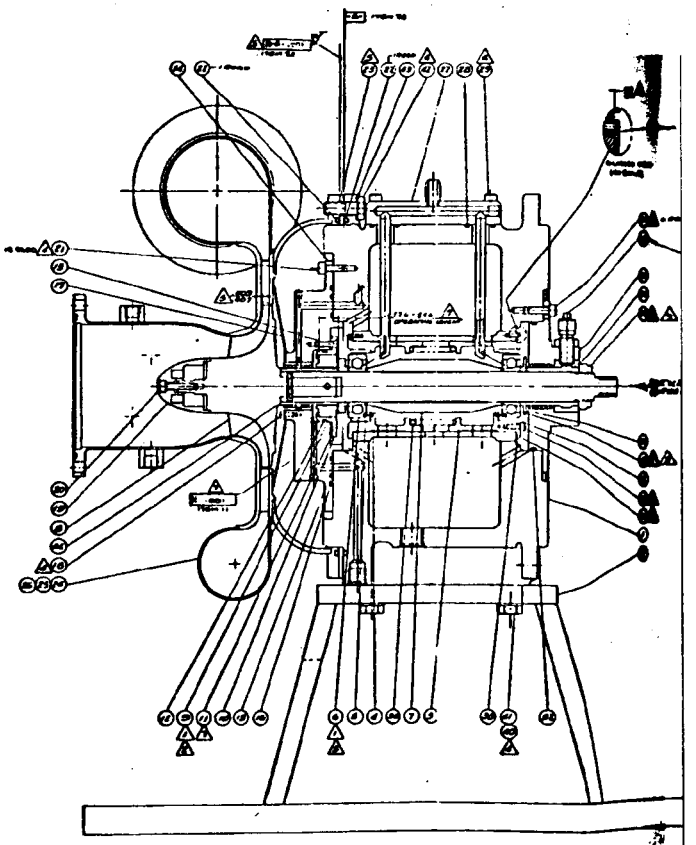
SCALE 1/1 WT SHEET 1

FOLDOUT FRAME 1

FOLDOUT FRAME 2

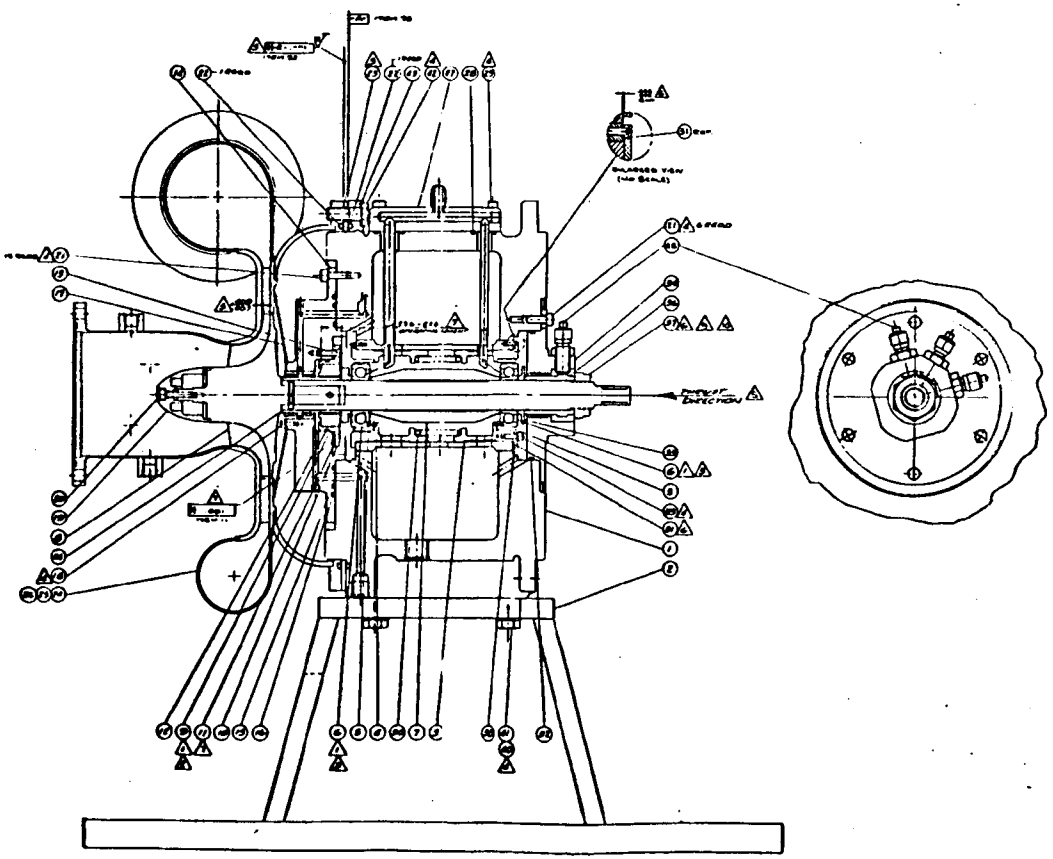






C99681

FOLDOUT FRAME 4/2

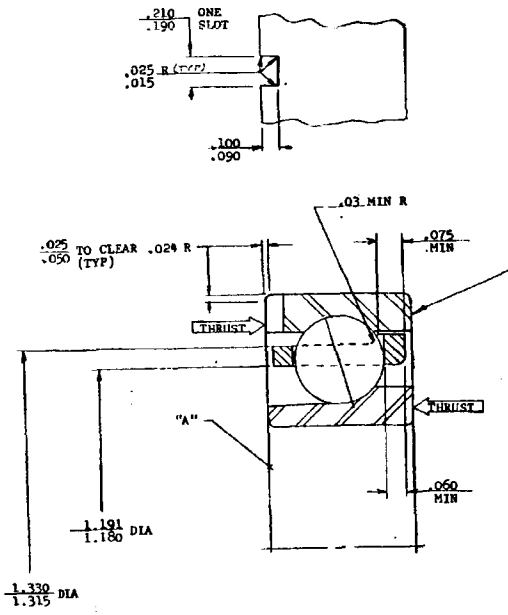


RESEARCH PACKAGE ASSEMBLY, COMPRESSOR

C99681

PART NUMBER 2
358500-1

REVISIONS			
LTR	DESCRIPTION	DATE	APPR
A	ADDED LEADER & ARROWHEAD	6-5-67	RAD.
B	INC DRN # 8140, SPEC. NOTE WAS: MARK PART NUMBER AND SERIAL NUMBER HERE PER AIRESEARCH SPEC. MC-5014 CLASS II	11/1/67	JH.
C	REVISED SPEC. NOTE WAS: MARK PART NUMBER AND SERIAL NUMBER HERE PER AIRESEARCH SPEC. MC-5014, CLASS II. MARKING ON O.D. OPTIONAL. SEE EO	11/10/67	TJC
D	ADDED .025 R (TYP) — SEE E.O.	7/31/68	TJC



MARK PART NUMBER AND SERIAL NUMBER HERE PER AIRESEARCH SPEC MC-5014, CLASS II OR III C MARKING ON O.D. OPTIONAL

See tab block (upper left corner) for PART NUMBER

BEARING DESCRIPTION: BALL, ANGULAR CONTACT, 7104 — GRADE: AIRESEARCH 5

INNER RING	OUTER RING	ASSEMBLED BEARING CHARACTERIST
MATERIAL: CEVM M-50 PER AMS 6490 Rc 60 MIN	MATERIAL: CEVM M-50 PER AMS 6490 Rc 60 MIN	TOTAL DIAMETRAL (M) CLEARAN
BORE: .7874-.7872 (20 MM) (M) TAPER/FT:	OD: 1.6535-1.6533 (42 MM) (M)	.0013-.0017 UNDER 1 LBS GAG
WIDTH: .4724-.4624 (12 MM) (M)	FLANGE OD:	SPECIAL FEATURES
RACE DEPTH: 20 MIN % BALL DIA	WIDTH: .4724-.4674 (12 MM)	1. FACES "A" TO BE FLUSH WITHI ±.0001 WITH 5 LBS THRUST LO APPLIED IN DIRECTION SHOWN.
RACE CURVATURE: 52-53 % BALL DIA	FLANGE WIDTH:	2. PARTS SHALL NOT CHANGE IN DIMENSION IN EXCESS OF .000050 IN/IN AFTER EXPOSUR TO 750°F FOR 10 HOURS.
SEPARATOR PILOT LAND TO GROOVE RUNOUT TIR	RACE DEPTH: 18 MIN %BALL DIA	3. SEPARATOR TO BE SILVER PLAT .0005-.002 THICK PER AMS 24
SEPARATOR	RACE CURVATURE: 52-53 % BALL DIA	4. CONTACT ANGLE 19° (REF).
MATERIAL: SILICON IRON BRONZE PER AMS 4616	SEPARATOR PILOT LAND TO GROOVE RUNOUT: .0005 TIR	5. SEPARATOR BALL POCKET SURFA CIRCUMFERENTIALLY FORE AND TO BE AT BEARING PITCH DIAM
CONSTRUCTION: MACHINED	ROLLING ELEMENTS	6. HEAT TREATMENT OF CEVM M-50 PER SPEC H-55.
ASSEMBLY: ONE-PIECE	MATERIAL: CEVM M-50 PER AMS 6490 Rc 60 MIN	7. BEARING TO BE NON-SEPARABLE UNDER NORMAL HANDLING.
PILOTING SURFACE: OUTER RING LAND	COMPLEMENT PER ROW: 11-9/32 DIA	
PILOT CLEARANCE: .006-.012	CLOSURES	
OPERATIONAL LUBRICANT	NUMBER: NONE	
NAME: OIL, SYNTHETIC, AIRCRAFT GAS TURBINE, LUBRICATING	TYPE:	
MILITARY SPEC NO.: MIL-L-7808	MATERIAL:	
BEARING PRELUBRICATION: DIP AND DRAIN	CONSTRUCTION:	

PACKAGING PER AIR. SPEC CP-14	PRODUCTION BULK PACK	COMMERCIAL SPARES PACK	MILITARY SPARES PACK
			MIL-P-197
PRESERVATIVE:	MIL-L-6085	MIL-L-6085	
AIRESEARCH PART NUMBER:	358500 -1	358500 -1	358500 -4
PROCUREMENT PER ASL	358500		

9 (C) (M) DESIGNATES CRITICAL CHARACTERISTIC / DESIGNATES MAJOR CHARACTERISTIC

8. PARTS SHALL CONFORM TO AIRESEARCH SPEC. SC-5354
7. PARTS PROCURED BY VENDOR PART NUMBER SHALL BE PROCURED IN ACCORDANCE WITH THIS AIRESEARCH SOURCE CONTROL DRAWING.
6. IDENTIFY PACKAGING WITH AIRESEARCH PART NUMBER.
5. ALL DESIGN AND PART NUMBER CHANGES SHALL RECEIVE PRIOR AIRESEARCH APPROVAL
4. ONLY THE ITEMS LISTED ON THE ASL AND IDENTIFIED BY VENDOR'S NAMES, ADDRESSES AND PART NUMBERS HAVE BEEN TESTED AND APPROVED FOR USE IN THE END UNIT. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY AIRESEARCH.
3. MILITARY SPARES PACK BEARINGS ARE INTENDED TO FILL MILITARY SPARES ORDERS. BEFORE INSTALLATION, WASH OUT THE PRESERVATIVE AND REPLACE WITH OPERATING LUBRICANT. AFTER THIS OPERATION THE -4 IDENTIFICATION IS CHANGED TO -1 AND THE BEARINGS BECOME INTERCHANGEABLE WITH THE PRODUCTION BULK AND COMMERCIAL SPARES PACK BEARINGS. THEY SHOULD NOT BE USED IN FACTORY INSTALLATIONS BECAUSE OF THEIR RELATIVELY HIGH COST.
2. FOR ECONOMY, PRODUCTION BULK PACK BEARINGS ARE PREFERRED FOR ALL FACTORY INSTALLATIONS. COMMERCIAL SPARES PACK BEARINGS ARE INTENDED TO FILL COMMERCIAL SPARES ORDERS.
1. PRODUCTION BULK AND COMMERCIAL SPARES PACK BEARINGS ARE INTERCHANGEABLE.

UNLESS OTHERWISE SPECIFIED:

CRITICAL ITEM

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SOURCE CONTROL DRAWING		
SIGNATURES	DATES	
DFT		11-1-67
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APPD		2-16-67
DESIGN ACTIVITY APPD		2-16-67
OTHER ACTIVITY APPD		

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

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